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Apollo Soyuz

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Preface

For two days in mid-1975 the crews of a combined U.S. and U.S.S.R. spacecraft orbiting the Earth at an altitude of 225 kilometers (140 miles) vividly demonstrated that men of divergent national and cultural backgrounds and loyalties can work together for common advantage. Their purpose was to flight test a mechanism for joining together two orbiting spacecraft.

Millions of viewers in many parts of the world watched live telecasts as three astronauts in a U.S. Apollo and two cosmonauts in a U.S.S.R. Soyuz merged their two spacecraft into a single vehicle. The TV audiences also saw the crews share meals, exchange gifts, and conduct scientific experiments, some of which produced remarkable and highly significant astronomical findings.

It was history's first international manned space flight and the first complex joint space project by the only two nations with proven capability to place men in orbit. The undertaking, called the "Apollo Soyuz Test Project," was a highly visible manifestation of the announced aspirations of the governments of the United States and the Soviet Union for a relaxation of tensions between the two world powers.

This publication summarizes the Apollo Soyuz record and presents a sampling of the thoughts and opinions this historic project evoked from the participants, the press, and other observers around the world.

Встреча

The Meeting

The time was shortly after 2 in the afternoon at Apollo Control at the Lyndon B. Johnson Space Center, Houston, Texas, Thursday, July 17, 1975, and shortly after 10 in the evening in Soyuz Control at Kaliningrad.

The television screens showed the interior of a pipelike corridor called the Docking Module connecting the U.S. Apollo with the Soviet Soyuz as the combined spacecraft orbited the Earth once every $1\frac{1}{2}$ hours.

The camera was focused on a closed hatch.

Two astronauts could be seen in their work clothes going through the required step-by-step procedures to open the hatch.

"Soyuz, our step 23 is completed," called one of the astronauts into the intercom. He was informing the two-man crew in the adjoining Soyuz of his progress. "We are now working on step 24." He spoke in Russian.

"We're through with that too," said the second astronaut. "Right here 25. Let me get the light on. . . . Camera. Yep, we're right on schedule. Okay there."

The dialog by the Americans came through loud and clear at Houston. In numerous training sessions the American and Russian crews and ground personnel had become thoroughly acquainted with the steps involved in opening the passageway from one spacecraft into the other.

"Okay to unlock?"

"The camera is running," interjected the unseen third U.S. crew member who was in the Apollo Command Module.

*Handshake in space.
Astronaut Stafford,
foreground, grasps
hand of cosmonaut
Leonov through port of
Docking Module that
links Apollo and Soyuz.*

"Right on schedule," repeated the first astronaut, glancing at his wristwatch.

"Hatch opening," shouted the second astronaut.

Thus, at 2:17 p.m. Houston Time (3:17 p.m. Washington Time), 10:19 p.m. Moscow Time, hatch number 3 swung open removing the last barrier between a U.S. and U.S.S.R. spacecraft. The U.S. TV camera that had been aiming at the hatch was now looking straight through the cylindrical passageway into the Soviet Soyuz. There the TV picture first showed some tangled, spaghetti-like communication cables.

"Looks like they've got a few snakes in there too," said the first American who had just disengaged himself from strands of unruly cable floating weightlessly in the Docking Module.

Then the TV screen showed movement at the far end of the passageway and the face and body of the Soyuz crew commander appeared. He was dressed in a flight outfit similar to the garments worn by the Americans. He stretched his arm forward through the passageway where his hand was clasped by that of the American crew commander.

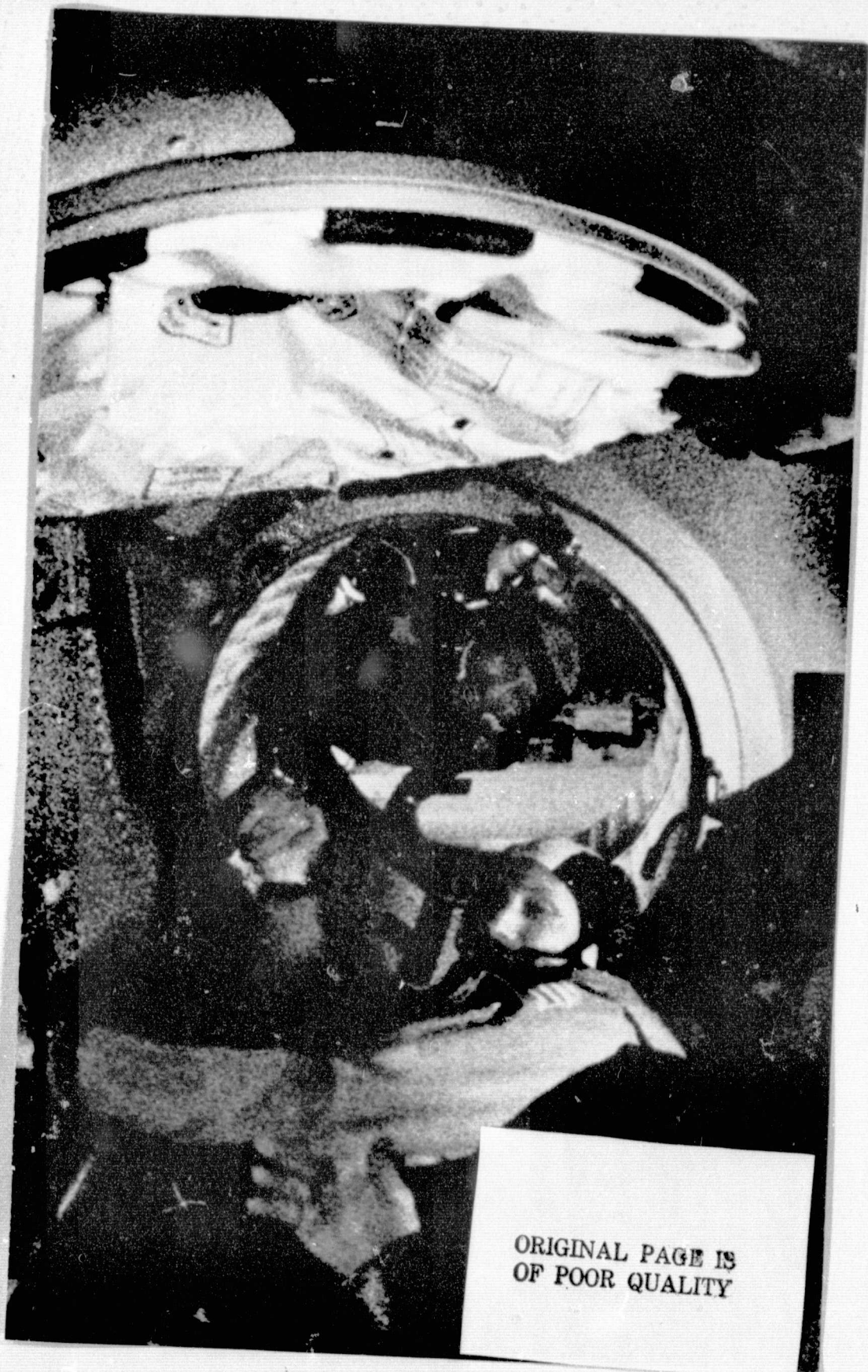
"Glad to see you," said the Russian in English with only a trace of an accent.

Thus, two veteran space explorers—U.S. Air Force Brigadier General Thomas P. Stafford, an astronaut since 1962, and Soviet Air Force Colonel Aleksey A. Leonov, a cosmonaut since 1960—met in Earth orbit.

As Leonov and Stafford held on to each other momentarily, their arms and hands formed a symbolic bridge between their nations. At last, the two nations in the endeavor—the only ones so far to have flown men in space—were working together rather than separately as they had through most of the period since the space age opened nearly 18 years earlier.

It was a day of many "firsts" and of much symbolism.

The historic handclasp occurred as the combined Apollo Soyuz was passing above Europe not far from the spot where American



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*Slayton and Leonov,
head to head, in
weightless space.*

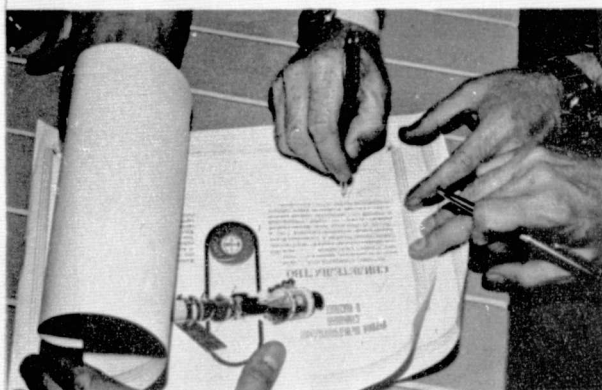


Stafford in Soyuz.

Flight certificate
is signed.

Leonov displays his
sketch of Stafford.

Kubasov, Soyuz host,
prepares fancy dinner
for fellow spacemen.



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and Soviet soldiers shook hands 30 years earlier in another symbolic gesture. Their armies had overrun Germany from opposite directions when they met at the Elbe River. That was near the end of World War II and their victories helped push both nations to the forefront of world power.

A few seconds after Leonov and Stafford released their clasp, the other American astronaut in the Docking Module, Donald K. ("Deke") Slayton, shook hands with Leonov, and then Stafford and Slayton shook another hand reaching through the passageway, that of Leonov's companion, cosmonaut Valeriy N. Kubasov. Within another minute Stafford floated weightlessly through the tunnel into the Soyuz Orbital Module and, for the first time, men of two nations were together in the same compartment in an orbiting spacecraft. Minutes later Slayton came through the same hatch to join Stafford, Leonov, and Kubasov in the Soyuz while the third U.S. crew member, Vance D. Brand, tended to the Apollo.

Facing the TV camera brought by Stafford and mounted in the Soyuz, the four men sat close to each other in the Orbital Module with an interior space about equal to that of a compact car.

The men listened as President Ford, talking by radiotelephone, congratulated both crews and then talked individually with each of the five. An hour earlier, when the two spacecraft already were joined, but before the hatch connecting them had been opened, a congratulatory message from Moscow was read to both crews by Victor Balashov, a Soviet television personality, on behalf of Communist Party Secretary Leonid I. Brezhnev. (Texts of the Ford and Brezhnev statements appear in Table A.)

The crews then gave each other sets of flags, medals, and other keepsakes and signed documents required by the Fédération Aéronautique Internationale for official recognition of the space flight records they were setting. They also completed operational tasks and used one of their onboard TV cameras to show Earth viewers sketches drawn by Leonov of his fellow Apollo Soyuz inhabitants.

Leonov and Kubasov were dinner hosts at a meal of Russian space foods including borscht, jellied turkey, cheeses, and miniature loaves of black bread.

By the time the Apollo crew was back in the Docking Module and the hatch was again secured, 3 hours and 34 minutes had elapsed.

Early the next day Leonov visited Apollo while Brand took his first look inside the orbiting Soyuz. A total of four such "crew transfers" and exchange visits were made so that each crew member was inside the other nation's spacecraft at least once during the two days the vehicles were linked. One crew member remained at all times in his own spacecraft to watch for possible malfunctions. All crews returned to their own couches and the familiar surroundings of their spacecraft during the hours set aside for sleep and rest. When the cosmonauts were in the Apollo, the astronauts served American space food.

During the 46 hours and 46 minutes Apollo and Soyuz were connected, the American and Soviet crews jointly carried out three scientific experiments. Later, after the spacecraft separated, they conducted two more joint experiments. Each crew also conducted a number of independent experiments.

Two days after the launches and slightly more than three hours before the hatch opening and handshake, TV viewers had watched the docking via a camera mounted in the Apollo's window. Observers on Earth had a closeup view as Stafford steered the Apollo smoothly toward the Soyuz until the two reciprocal docking mechanisms touched. This set off an automatic sequence of actions that caused docking latches to hook and close and the petal-like guides on each spacecraft to interlace, like fingers intertwining, to lock the two space vehicles together.

"Less than five meters' distance." The announcement had come from Stafford in Russian. He was talking with his Soyuz colleagues in the staccato style of test pilots and spacecraft crews in situations requiring split-second timing, but he could also be heard by the rest of the world.

"Three meters."

"One meter."

"Contact."

From Soyuz came the reply in English:

"Capture."

"We also have capture," said Stafford in Russian. "We have succeeded. Everything is excellent."

"Soyuz and Apollo are shaking hands now," said Leonov.

"Close active hooks," called Stafford. "Docking completed." Then, addressing himself in English to his ground controllers, he repeated: "Docking is completed, Houston."

And a voice from inside Soyuz spoke up: "Well done, Tom. It was a good show. We're looking forward now to shaking hands with you on board Soyuz."

During that first get-together in Soyuz, the crews held a press conference—the first such in-flight session with an international crew—in which they answered questions read to them by spacecraft communicators. The questions came from newsmen in Houston and Moscow.

At the beginning of the conference, Stafford recalled the thoughts that had gone through his mind as Slayton and he were preparing to open the passageway between the craft.

"When we opened this hatch in space," Stafford told the press representatives, "we were opening, back on Earth, a new era in the history of man."

Leonov, who sat next to Stafford during the press conference inside the narrow Soyuz, had expressed his thoughts in his own way shortly before the start of the flight.

"Together we have begun an irreversible thing," he had said. "The machine of Apollo Soyuz is operating now and no one can stop it."

The Mission

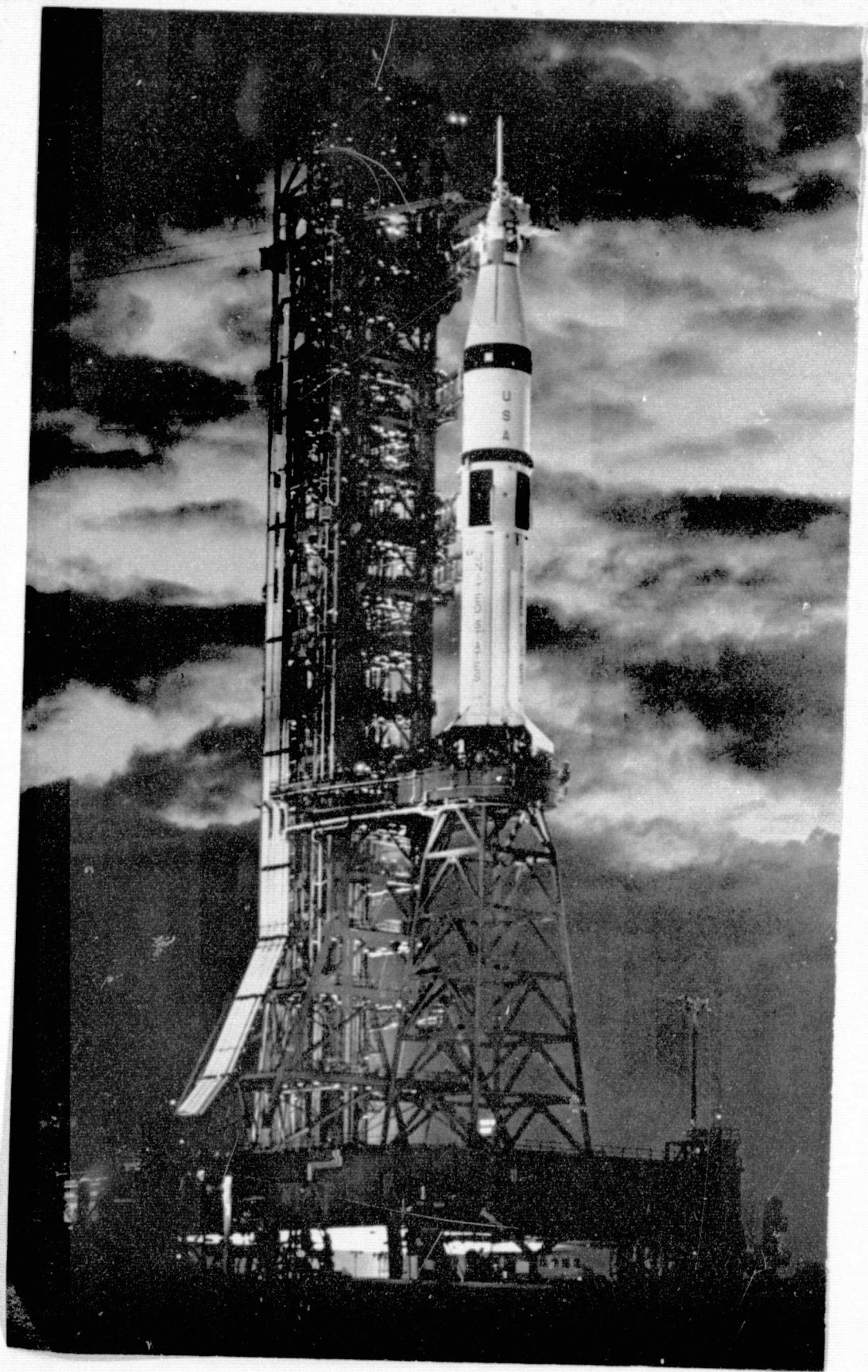
The joint flight had started on two widely separated continents with launches as close to perfection as anyone could wish.

The first took place at the Baykonur Cosmodrome on a central Asian desert plain near Tyuratam, east of the Aral Sea, in the Kazakhstan Republic of the Soviet Union. The site is about 3200 kilometers (2000 miles) southeast of Moscow. An SL-4 launch vehicle sent the Soyuz 19 spacecraft, with cosmonauts Aleksey A. Leonov and Valeriy N. Kubasov aboard, off its pad on Tuesday, July 15, at 8:20 a.m. (EDT) Washington time (3:20 p.m. Moscow time)—only 0.005 second later than the scheduled time.

Seven and one-half hours later—at 3:50 p.m. Washington time (10:50 p.m. Moscow time)—the Apollo with its three-man crew was lifted skyward by a 67-meter (224-feet) high Saturn 1B rocket at the NASA Kennedy Space Center on the shores of the Atlantic Ocean in Florida. It was a scene like those shown on TV, film, and still photography many times over the years. The U.S. liftoff also came within a fraction of a second (0.085 second) of its planned time. Thus began the world's 57th and 58th manned space flights—the 31st for the United States, the 27th for the Soviet Union.

These normal launches were exceptional because of their spectators.

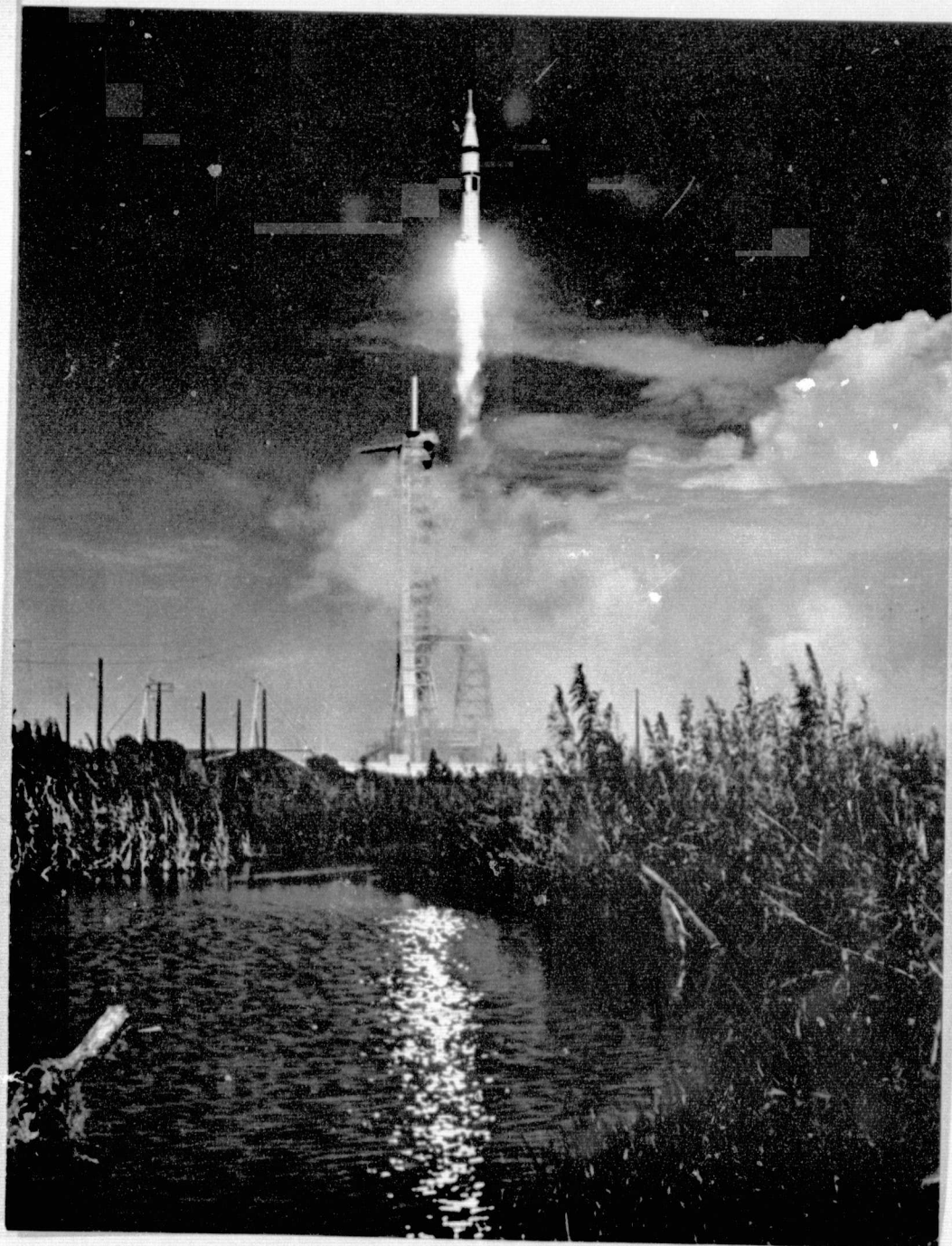
Watching the Soviet launch at a television receiver in an auditorium at the U.S. Department of State in Washington was President Ford. At his side sat the Soviet Ambassador to the United States, Anatoliy F. Dobrynin. After the launch, Ambassador



*Apollo/Saturn 1B
on launch stand.*

*Apollo/Saturn 1B
thunders from
launch site.*

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Dobrynin flew with the Administrator of the National Aeronautics and Space Administration, Dr. James C. Fletcher, to the Kennedy Space Center where they saw Apollo rise from its pad.

At Baykonur watching the liftoff was the U.S. Ambassador to the Soviet Union, Walter J. Stoessel; his wife; Egon E. Loebner, a science officer from the U.S. Embassy in Moscow; and Dr. Willis Shapley, personal representative of the NASA Administrator. The four were the first Americans to be present at a Soviet space launch. Few persons from outside the Soviet Union had ever been permitted to observe Soviet launches.

The Soyuz 19 liftoff was the first Soviet launch ever shown on live television. The telecast was seen in the U.S.S.R. and around the world.

The Soyuz entered a slightly elliptical orbit with a high point of 222 kilometers (140 miles) and a low point of 186 kilometers (117 miles) above the Earth. Subsequently, the cosmonauts adjusted their orbit (through short firings of their spacecraft engine) to a more circular, slightly higher flight path.

Through a series of complex maneuvers carried out with the help of computer calculators, the Apollo gradually steered itself from its slightly lower orbit to the vicinity of the Soyuz. Each spacecraft was completing a revolution of the Earth about every 88 minutes.

Astronaut Brand made the first sighting of the Soyuz from Apollo, while looking through a sextant, when the two spacecrafts were still about 400 kilometers (250 miles) apart.

From then on, the distance between the two spacecraft kept narrowing with each orbit. The astronauts maneuvered their Apollo into formation flight with the Soyuz and then linked the two spacecraft, demonstrating the workability and reliability of the rendezvous and docking systems. The historic union occurred at 12:09 p.m. Washington time (7:09 p.m. Moscow time), July 17, 1975, above the Atlantic Ocean about 1150 kilometers (720 miles) west of Portugal.

For the next two days, the crew members crawled through the Docking Module from one spacecraft to the other and back again, verifying, in weightlessness, the techniques and equipment designed to make possible such transfers, and they performed a variety of scientific and technological experiments. In completing these assignments, the crews accomplished all major flight objectives.

The primary objective of Apollo Soyuz was to demonstrate the feasibility of a joint docking system that would make possible future cooperation in space between the United States and the Soviet Union. Without a compatible docking system, each nation would continue to be limited, for the most part, to its own independent space activities during a period when research and practical applications in Earth orbit are steadily increasing in value. A standardized docking mechanism is an essential first step toward the operation of Earth-orbiting space stations supplied and staffed by nations working together for common interests.

After a farewell handshake and a return to their own spacecraft, the men sealed the hatches for the last time and on July 19, at 8:03 a.m. Washington time (3:03 p.m. Moscow time), the two spacecraft undocked. Half an hour later, as a practice exercise and as an additional check on the workability of the docking system, the crews reconnected their craft for an additional three hours. Then the Apollo and Soyuz undocked for the last time and slowly drifted apart, each going its own way with its own individual flight plan in different orbits. The joint phase of the mission was over.

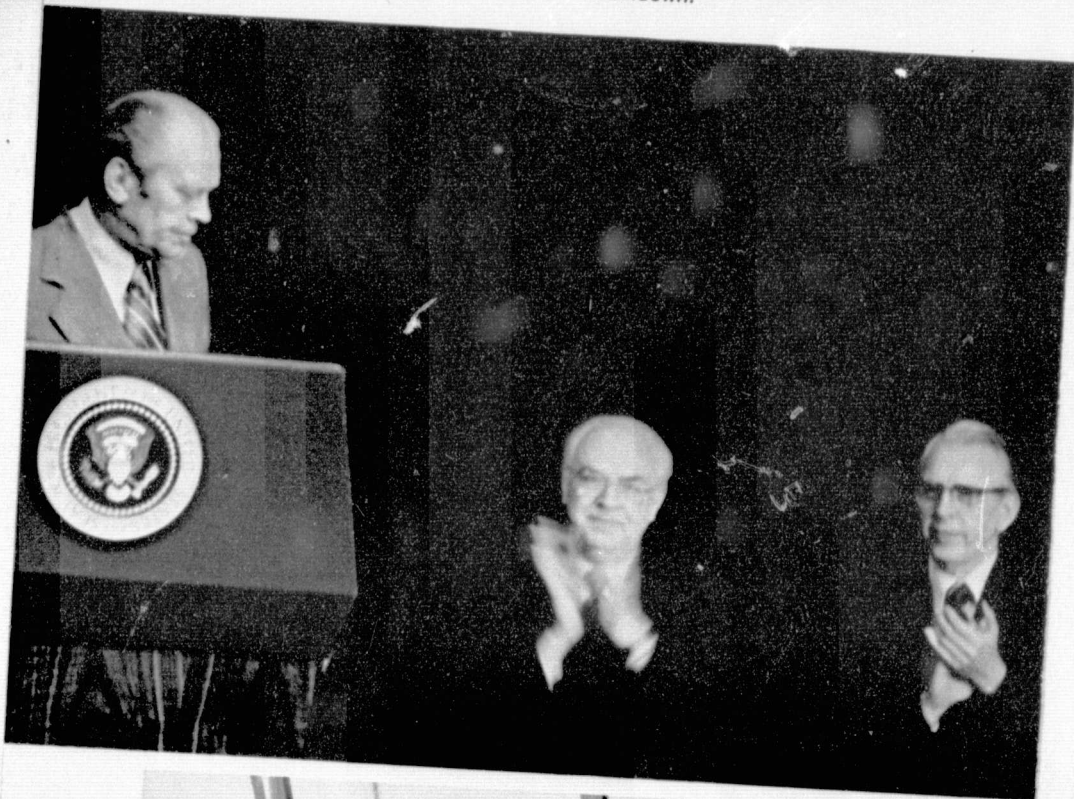
Two days later, after nearly six days in space, the Soyuz landed at 6:50 a.m. Washington time (1:50 p.m. Moscow time) in south central U.S.S.R. about 3200 kilometers (2000 miles) southeast of Moscow. Like the launch, the parachute descent and landing were shown on live television, the first time the Soviet Union had authorized such a telecast.

Viewers who had seen numerous U.S. spacecraft splashdowns had long wondered what a Soviet space landing was like. They

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Left to right, President Ford,
Soviet Ambassador to the United
States Anatoliy F. Dobrynin, and
NASA Administrator James C.
Fletcher at U.S. Department of
State to watch launch of Soyuz
on TV.

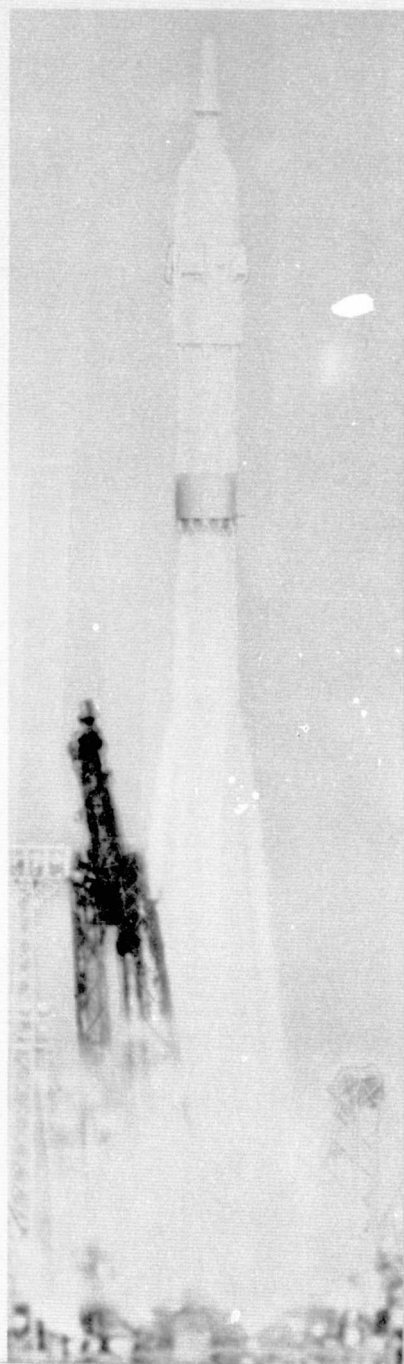
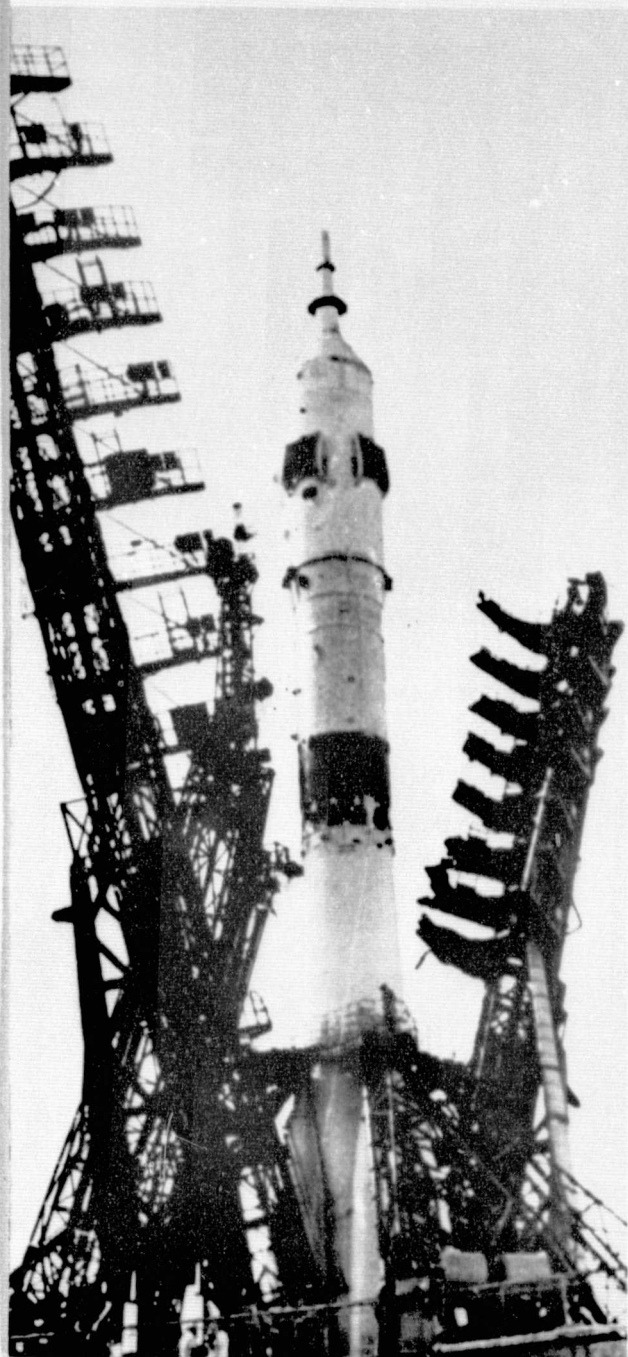
Soviet Ambassador to the United
States Anatoliy F. Dobrynin
(center), NASA test conductor
Richard Thornburg (right), and
NASA Administrator James C.
Fletcher in Florida launch control
Firing Room 3 during Apollo
countdown.



*Soyuz space vehicle
on pad.*

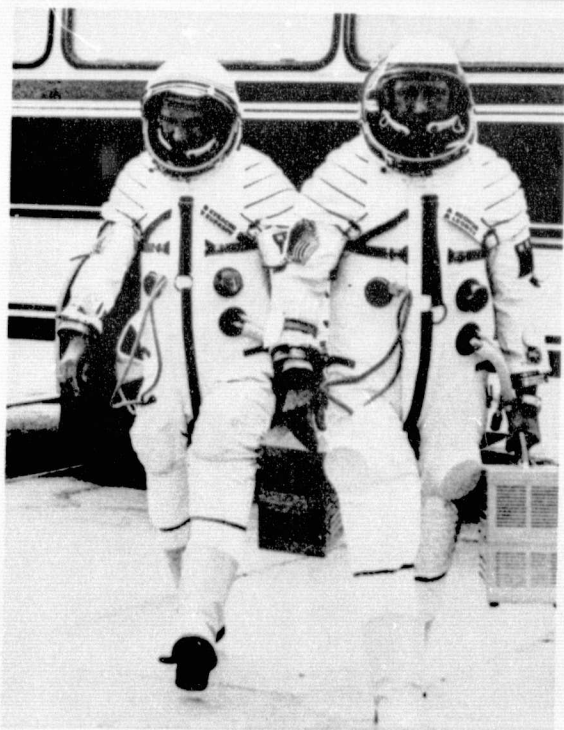
Soyuz liftoff.

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*Stafford, Brand, and
Slayton enter transfer
van for trip to
launchpad.*

*Kubasov (left) and
Leonov leave their
transport van and head
for launchpad.*



Slayton.

Stafford (left) and
Leonov.

Kubasov.

Brand.

Brand crawling
through Docking
Module.

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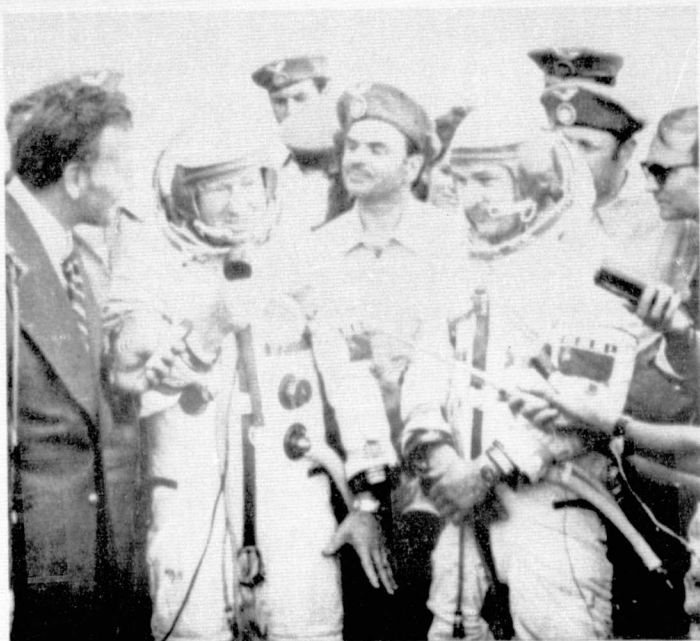


*Soyuz as seen from
Apollo.*

*Kubasov autographs
Soyuz Descent Module
after landing. Lecnov
is at right.*

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*Leonov (center) and
Kubasov (right) talk
with newsmen after
landing.*



watched with great interest as the bell-shaped Soyuz Descent Module floated earthward under a single striped orange-and-white parachute. Rockets attached to the underside of the module were ignited when the spacecraft was only a few meters from the ground to cushion its impact, and they added to the cloud of dust that swirled around the spacecraft as it touched down in the desert. The telecast of the landing came from helicopters that flew around Soyuz during its descent. Recovery teams were on hand within moments after touchdown. The cosmonauts stepped out of the capsule with visors up and appeared to be smiling.

The Apollo carried more fuel and other supplies than the Soyuz and, thus, was able to remain in space longer. American officials also wanted to make the most of the flight opportunity for scientific and technological research. Apollo's five extra days in orbit, beyond the joint flight phase, were used primarily for research purposes.

This research (and also experiments carried out independently by the Soyuz crew) fulfilled or exceeded expectations. (See Chapter 6: "The Scientific Experiments.")

A number of relatively minor equipment problems during the flight were overcome or compensated for without any effect on the accomplishment of mission objectives.

The flight's only serious untoward happening occurred during the return to Earth of the Apollo on July 24 after nine days in space. (See Chapter 9: "The Reentry.")

The primary flight objective—the demonstration of the joint docking system—was achieved as flawlessly as anyone could have hoped.

Apollo Soyuz showed that rescue missions and aid to space crews in distress will be feasible in the future on an international scale, and that cooperation in space research and operations can be of advantage even when the crew members come from countries with different languages, customs, cultures, and political systems.

The mission, which many doubted would ever take place in

view of technical, political, ideological, and national security barriers, was now on the record books. The Apollo Soyuz Test Project, which brought the United States and the Soviet Union together in a monumental hands-across-the-sky display of cooperation and technological prowess, was now history.

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The Background

The Apollo mission covered only 9 days, 8 hours, and 59 minutes, but the negotiations that led to the joint flight with Soyuz and the intensive preparations for it stretched over many years.

The international character of space activities was recognized, and the concept of men from many nations exploring space together was accepted from the beginning of the space age.

Shortly after the launching of the first artificial Earth satellites in the late 1950's, both the Soviet Union and the United States endorsed the principle of international cooperation in space. But this cooperation between the two nations was slow in coming.

One reason was simply that some aspects of pushing spacecraft into orbit did not lend themselves readily to sharing with a competitor in other fields. For example, powerful rockets and their guidance systems have obvious military applications. There was little desire by either country to give away technology on which national security might depend.

But even in those early days of the space age, NASA announced its willingness to engage in cooperative scientific projects in space.

In the early 1960's the United States was involved in cooperative programs with several nations for launching sounding rockets in studies of the upper atmosphere at the edge of space. In 1962, U.S. rockets participated in history's first international orbital projects by launching satellites built and owned by other countries: the United Kingdom's Ariel and Canada's Alouette. Through most of that decade the United States was engaged in

cooperative space projects with dozens of nations.

But cooperation with the Soviet Union—the only other nation able to send men into orbit and automated craft to the Moon and planets—was very limited.

The United States had made several approaches to Soviet officials, and in 1962, when John Glenn became the first American in orbit, Soviet Communist Party Chairman Nikita Khrushchev's congratulatory telegram included a statement about the desirability for cooperation between the two nations in the exploration of outer space.

In response, President Kennedy sent a letter to Khrushchev proposing joint establishment of a world weather satellite system through coordinated satellite observations and data exchange. In addition, the American President suggested exchanges of spacecraft tracking services and sharing of the task of mapping the Earth's magnetic field by exchanging data gathered by satellites. His letter also invited the Soviet Union to join other nations then establishing ground terminals for testing intercontinental communications satellites.

When the first agreement on space cooperation between the United States and the Soviet Union was signed in June of that year (1962), some of the earlier proposals showed up in it. Signing were Anatoliy Blagonravov of the Soviet Academy of Sciences and Hugh L. Dryden, NASA Deputy Administrator. The agreement called for relatively little joint activity, but it was a beginning. It provided for exchange of data from weather satellites and of information about the Earth's magnetic field obtained through satellite launches, and a communications experiment using the U.S. Echo satellite.

A Soviet suggestion led to another agreement in 1965. It called for only a relatively small-scale project—a joint review of the experiences of the two nations in space biology and medicine—but that became the first joint effort in a field related to manned space flight. Work began in 1969, and the text of the three-volume joint review was approved for publication by the U.S. and

Pages 32 and 33. May 24, 1972, a historic date. President Nixon and Premier Kosygin, Chairman of the U.S.S.R. Council, sign an agreement on cooperation in space between the United States and the Soviet Union. The agreement included Apollo Soyuz.

U.S.S.R. editorial board a few months before the Apollo Soyuz flight.

Until the first manned landing on the Moon (Apollo 11, July 20, 1969), efforts by NASA officials to broaden space cooperation with the Soviet Union bore little fruit. However, throughout 1968 and 1969, with the support of the U.S. President and with the knowledge of leaders of Congress, NASA Administrator Dr. Thomas Paine continued to press the Soviet side. In late 1969, he sent to Mstislav V. Keldysh, President of the Academy of Sciences of the U.S.S.R., copies of reports on U.S. long-range goals in space. Dr. Paine asked Keldysh whether any of the listed U.S. objectives might lend themselves to cooperative projects beyond the very limited ones already in existence between the two nations. He proposed the two sides meet to discuss their interests.

In reply Keldysh suggested that a meeting on the subject be convened in several months.

During that interval U.S. officials suggested that the cooperation might take the form of joint dockings in space. In October 1970, representatives of NASA and the Soviet Academy of Sciences met in Moscow for what turned out to be the first of a series of sessions that were held alternately in the Soviet Union and the United States.

At that October meeting, NASA and the Soviet Academy agreed to set up "working groups" of specialists to study the elements of compatible rendezvous and docking systems.

At one of the followup meetings, in January 1971, Dr. George M. Low, NASA Deputy Administrator, suggested to Keldysh that U.S. and U.S.S.R. manned spacecraft be considered for flight testing the new rendezvous and docking systems being developed. At another Low-Keldysh meeting in April 1972, the U.S. and Soviet delegations agreed that such a test flight would be desirable.

The main achievement of this April meeting was agreement on the procedures, relationships, mutual access and training, communications, testing, other activities, and conditions required for management of the joint effort.





In the meantime, technical experts of the working groups met to talk about the radio and visual systems needed to make it possible for the Apollo and Soyuz to find each other and meet in space and the communications, tracking, and environmental systems the joined spacecraft would need, as well as the mechanisms for docking and the mission operation plan.

Thus, many of the basic plans and procedures already were firmly established when President Richard Nixon and Aleksey Kosygin, Chairman of the U.S.S.R. Council of Ministers, signed an agreement in Moscow on May 24, 1972, "concerning cooperation in the exploration and use of outer space for peaceful purposes." The agreement was one of several signed by the two leaders that same month for cooperation in a wide spectrum of science and technology, and it approved the idea for an Apollo Soyuz test flight and the arrangements made for it up to that time.

From the time of the signing of the May 1972 agreement, preparations for the Apollo Soyuz mission were in high gear.

Crews and alternates were selected and began their training. Officials were assigned on both sides to manage the mission.

One of the most serious obstacles worrying flight officials was the language difference. Crew safety and joint operations demanded quick, accurate exchange of information during the flight. Astronauts began taking Russian lessons and the cosmonauts began studying English. By the time the flight began, the U.S. flight crew had gone through more than 700 hours of instruction in the Russian language. During the joint phase of the flight, the American crew spoke in Russian and the Soviet crew spoke in English.

The American crews—the three-man prime crew, three-man backup crew, and three-man support crew—flew to the Y. A. Gagarin Center for Cosmonaut Training at Star City near Moscow for joint training with the Soviet crews (the two-man prime crew and three two-man backup crews). The Soviet crews, in turn, traveled to the NASA Johnson Space Center in Houston for

Dr. George M. Low, NASA Deputy Administrator, uses model to answer Apollo Soyuz questions. Next to him is Boris M. Petrov, chairman of the Soviet Intercosmos Council and leader of the Soviet mission-planning delegation that visited Johnson Space Center in 1972.

Crews with model of docked Apollo and Soyuz. Left to right are Stafford, Brand, Slayton, Leonov, and Kubasov.



training and flight simulation sessions.

Engineers and technicians from both nations spent scores of hours at each other's Mission Control rooms for discussions and training to support the mission. Interpreters learned the jargon used by engineers of the United States and the jargon of the Soviet engineers. Translation problems were formidable for the mission control crews and for the technical negotiators as well.

In the three years after intensive preparations began for the Apollo Soyuz, 44 meetings took place, alternately in the United States and the Soviet Union, by six "working groups" of technical experts. Each group had from 5 to 20 members.

One group was concerned with negotiations for rendezvous systems and docking mechanisms that allowed the originally incompatible Soyuz and Apollo to link as a single orbiting vehicle.

Another group arranged the elaborate communications network that allowed continuous contact between the Houston and Kaliningrad control centers with voice transmission lines, television lines, Teletypewriter lines, and lines for Telex and Datafax (transmission and reproduction of text and graphic materials). The group also arranged for communications between the flight crews by radio, and after docking, by intercom using a cable between the joined craft.

Other working groups were concerned with tracking and guidance, life support, crew transfer, coordination of control centers, and overall mission planning.

After agreement had been reached on the specifications for the docking system, engineers of both sides went to their drafting boards and work benches and independently designed and built docking hardware for their respective spacecraft. The Americans built an electrohydraulic system, the Soviets an electromechanical system, but both were designed to match perfectly in space. (See Chapter 4: "The Spacecraft.")

At a 1972 meeting in Moscow of the working group concerned with these docking systems, the Americans brought along a model two-fifths the size of the unit planned for the flight. The

Soviet engineers had also constructed a two-fifths scale model of their flight unit.

Both units were on wheeled tables. During the meeting the engineers pushed the two tables together so that the models met and interlocked exactly as intended, thereby verifying the design concepts and illustrating the space operation planned for three years in the future.

Subsequently, exact duplicates of the U.S. and Soviet flight units were similarly docked and undocked hundreds of times in simulations under a wide variety of possible space conditions such as in very high and very low temperatures. Again, the units performed as intended.

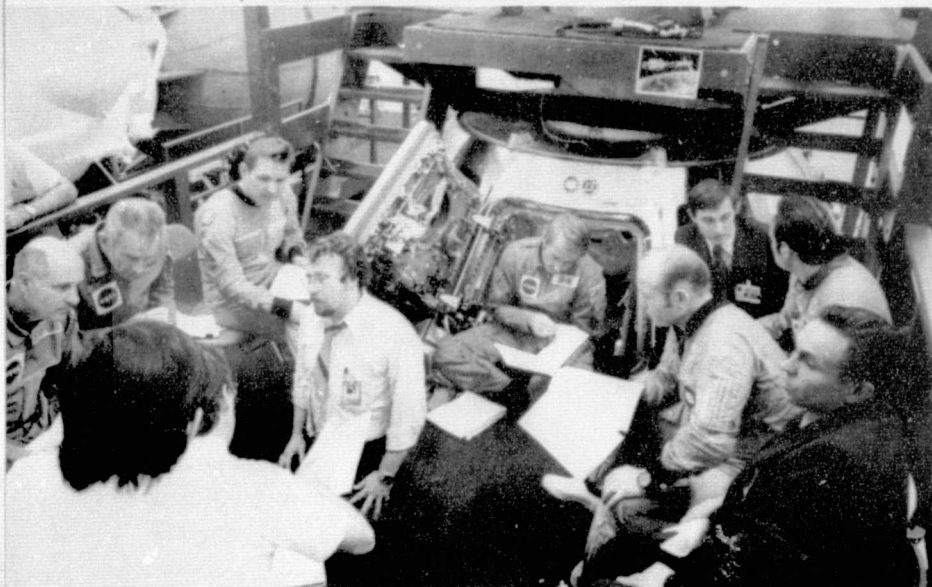
In the course of the negotiations, the two sides compiled a dictionary of common terminology. It was a listing of terms and their meanings mutually agreed upon and it was very helpful to translators who memorized most of it. Also out of the negotiations emerged two large volumes. One was entitled "Onboard Joint Operations Instructions" and was carried on each spacecraft. Half of each page was in English and the other half, with the same text, was in Russian. The book contained detailed information on every step for every planned procedure by the flight crews during the joint phase of the mission. The other volume contained equally detailed information on every aspect of mission control operations that concerned both centers.

In compiling these documents, the negotiators tried to foresee not only each step in a normal mission but also any unusual or emergency situation that could conceivably occur and the precise procedures on how to deal with it.

The U.S. program director for Apollo Soyuz, Chester M. Lee, said, "Just getting two control centers thousands of miles apart to understand and communicate with each other" was one of the "great accomplishments" of the project. He said the lessons learned from the experience will save time and money in any future joint undertakings of this kind.

One of the radio communications problems foreseen for the

Crewmen wearing flight suits engage in joint training at Johnson Space Center. From left to right, they are: Stafford, Slayton, Kubasov, Brand, Leonov, and Vladimir A. Dzhanibekov, commander of the Soviet third backup crew. Others in the picture are training personnel and interpreters.



Stafford (left) and Leonov plant birch tree at Star City, near Moscow while Slayton (behind Stafford) observes.



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mission was that the existing ground stations and ships would permit only intermittent contact with crews for less than one-fifth of the time of an average orbit.

Because of the relatively low altitudes of the Apollo and Soyuz (compared to Moon flights), the spacecraft would be in line-of-sight contact with Earth stations for only about 17 percent of the flight time. Telecasts and conversations with mission controllers would have to be kept very short and be few in number. Rarely would the crews be in continuous radio contact with the Earth for more than a few minutes at a time.

To improve the communications capacity, NASA placed its experimental Applications Technology Satellite (ATS) 6, by far the most powerful communications satellite ever built, at the disposal of the Apollo Soyuz managers.

The satellite, far above, at an altitude of 35 680 kilometers (22 300 miles), was in line of sight of the Apollo and Soyuz spacecraft for about half of their 88-minute orbits and, thus, the satellite, together with the ground stations, made possible prolonged continuous telecasts and broadcasts from the astronauts and cosmonauts. Ground radio contact was increased to about 55 percent of the flight time.

It was the first time in history that manned spacecraft communicated with ground controllers via an orbiting satellite and, because of the Applications Technology Satellite, millions of people in many parts of the world were able to see and hear much of the happenings on the two spacecraft.

The flight phase of Apollo Soyuz was the culmination of about 3 years' work for many persons who had been involved from the beginning. For them, most of the flight seemed much like the replay of an old movie—they had been through numerous realistic simulations—except for the human touches that do not come out in rehearsals, such as when the cosmonauts boarded their Soyuz shouting to bystanders in Russian: "Go to the devil." The phrase is a common Russian saying equal in meaning to the American idioms "knock on wood" or "wish me luck."

In training and simulations, spacecraft crews and ground controllers were deliberately confronted by myriad contrived malfunctions and other serious problems to teach them to cope with difficulties. In the flight itself, no problems serious enough to fluster anyone occurred, and the mission proceeded with a smoothness that delighted crews and controllers. After all the relentless and sometimes frustrating planning, bargaining, suggesting, revising, and practicing, the flight of Apollo Soyuz seemed to many of the people involved in it the shortest 9 days, 8 hours, and 59 minutes they had lived through in many years.

Космические корабли

The Spacecraft

APOLLO

A Greek and Roman god, associated with light, music, healing, poetry, prophecy, and manly beauty.

—also, a three-man U.S. spacecraft designed for flights to the Moon and back.

SOYUZ

A Russian word meaning "union" or "alliance."

—also, a spacecraft for transporting two men into Earth orbit and back.

Together, they formed a strange-looking assembly. If the joined spacecraft could have been seen in closeup from the ground as they orbited the Earth, they would have appeared like a random array of odd-shaped cylindrical and spherical units. They formed a cluster—somewhat resembling an irregularly weighted barbell—20 meters (66 feet) long, with a diameter of 3.9 meters (13 feet) at the widest parts, and a total weight of 21 500 kilograms (47 500 pounds).

Both spacecraft had, individually, already carved out a very prominent place in the history books of space exploration. Their joint participation in the Apollo Soyuz Test Project added another page to their already illustrious records.

The Soyuz made its first space flight in April 1967, the Apollo in October 1968. Both had been the workhorses of space for the nations that built them. Each had carried more men into space and back on more journeys than any other vehicle built by its country. Each was a third-generation spacecraft—the three-man

Apollo was derived from the smaller, less sophisticated one-man Mercury and the two-man Gemini; the Soyuz was developed from the Vostok and Voskhod.

The Apollo had been designed to transport men to the Moon and back while Soyuz—smaller, lighter, and with less fuel and weight-carrying capacity than the Apollo—had been designed for missions in Earth orbit.

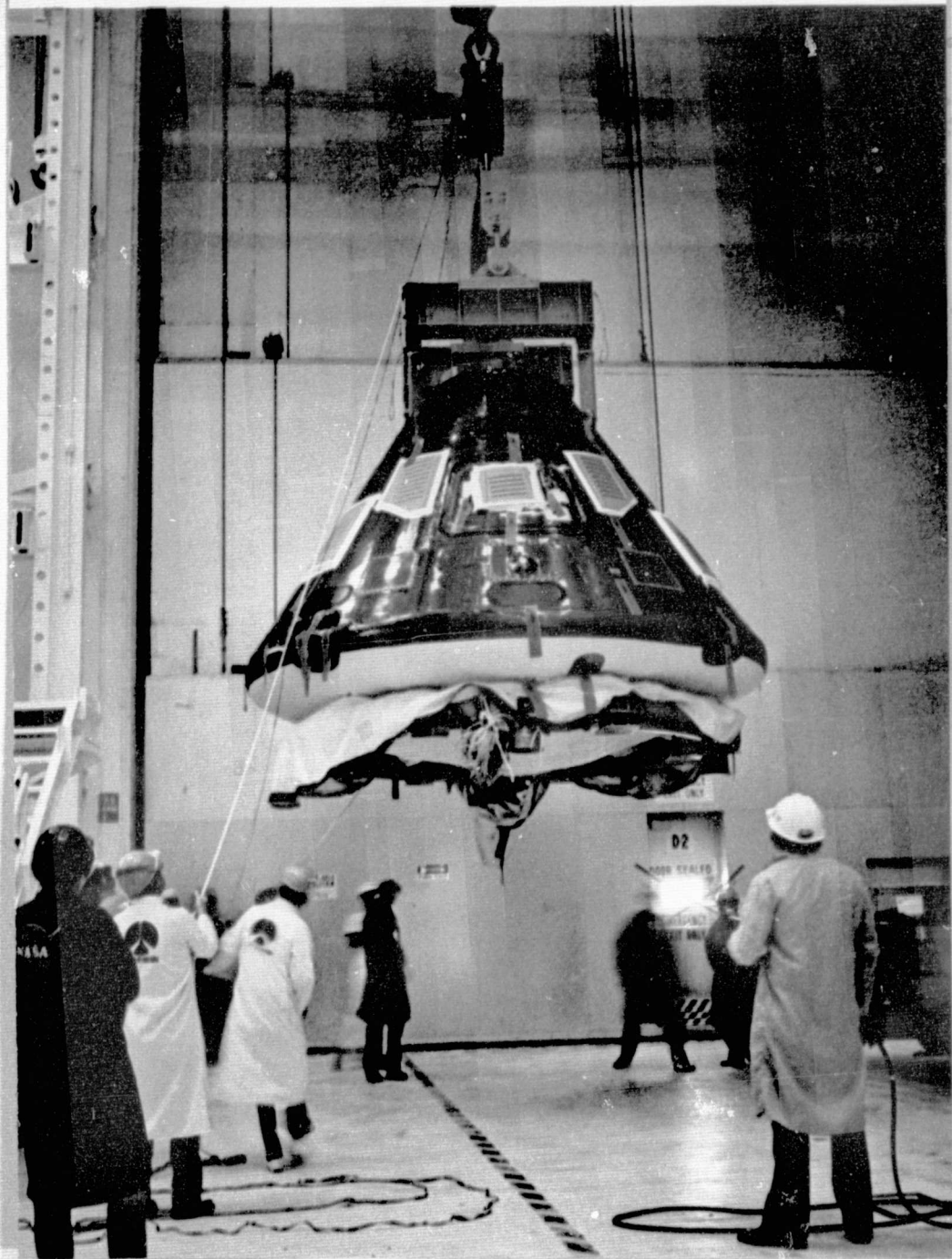
While the United States had conducted earlier dockings in space between a manned and an unmanned spacecraft, the first docking of two manned orbiting spacecraft and the first transfer of men from one orbiting spacecraft to another was accomplished by Soyuz 4 and 5 in January 1969. The first mission in which three manned spacecraft were in orbit simultaneously, with a total of seven men on board, involved Soyuz 6, 7, and 8 in October 1969. Soyuz 10, in April 1971, achieved the first docking of a manned spacecraft with a space station (Salyut).

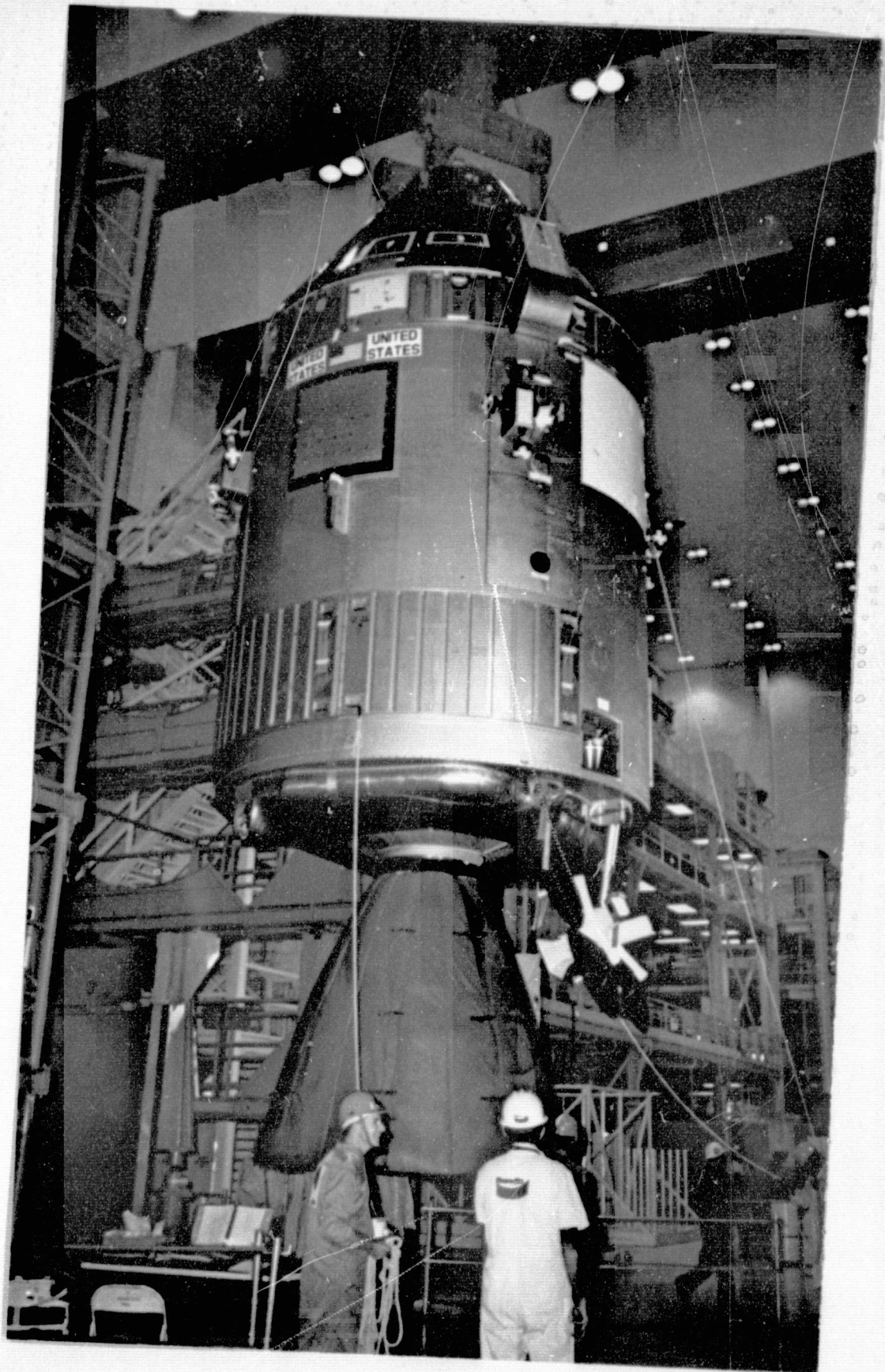
A forerunner of the Apollo spacecraft, the U.S. Gemini, had been the first steerable manned spacecraft with which astronauts could maneuver from one orbital path to another (as they did for the first time in the Gemini 3 flight in March 1965)—an ability that is crucial to rendezvous (formation flight) and docking. Another Gemini became the first manned spacecraft to dock with an unmanned orbiting object—Gemini 8 did this in March 1966 with an Agena rocket engine that had been sent into space earlier. These feats were accomplished during the period while the Soyuz and Apollo were being developed.

The Apollo, however, was the vehicle used for the most spectacular series of achievements in space: Apollo 8 carried men around the Moon for the first time in history in December 1968 and, thus, allowed men to see with their own eyes the Moon's farside, which never faces the Earth. Apollo 10 extended the 10 Moon orbits of Apollo 8 to 31 and demonstrated history's first rendezvous and docking in lunar orbit (by Apollo's Command/Service Module and its detachable Lunar Module—both manned).

*Apollo Command
Module after arrival at
Kennedy Space
Center.*

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*Apollo Command/
Service Module is
checked out at
Kennedy Space Center
prior to mating with
Saturn 1B launch
vehicle.*

The climactic event of all space exploration to date was, of course, the historic flight of Apollo 11 in July 1969 in which men landed and walked on the Moon. Thus, Apollo became the bridge on which men for the first time in world history reached another celestial body.

For the American and the Soviet spacecraft to join together in orbit, several modifications had to be made to each. The new compatible docking system had to be accommodated, and a chamber had to be built through which the men could pass from the internal atmosphere of one spacecraft into the different atmosphere of the other.

This connecting link between the two craft—designed and built by the United States—was called the Docking Module. The module was basically a cylindrical aluminum corridor 3.15 meters (10 feet, 4 inches) long and 1.4 meters (4 feet, 8 inches) at its widest diameter weighing 2012 kilograms (4436 pounds). Inside or attached to it were containers for gases to replenish the atmosphere, radio and television and other communications equipment, and research apparatus including a small electric furnace.

The astronauts used the module also as a bedroom (Slayton slept in it several times to make more room for the other crew members in the Apollo Command Module), as a storeroom for equipment, as a den for friendly conversations during transfers with Soviet crew members, and, of course, as an airlock—a chamber in which the atmosphere is changed to that of the craft about to be entered.

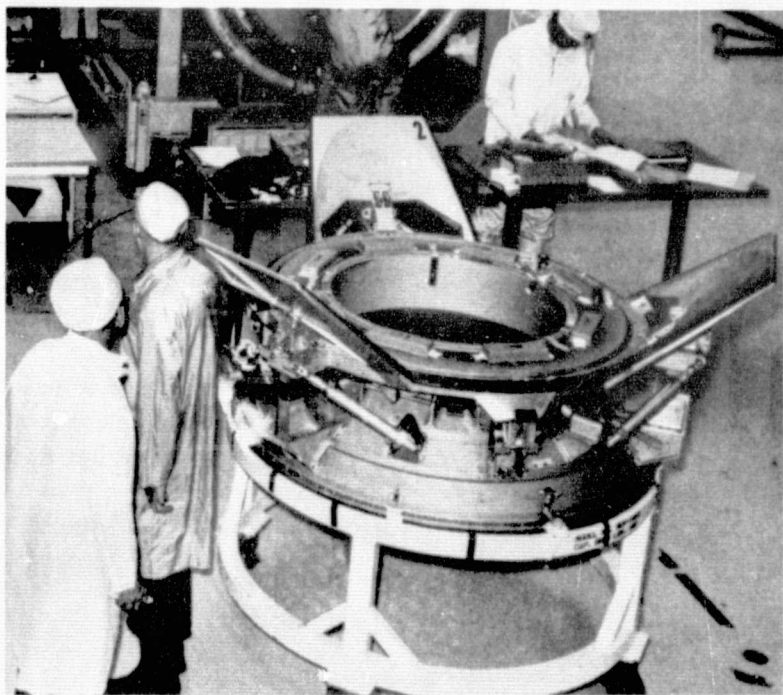
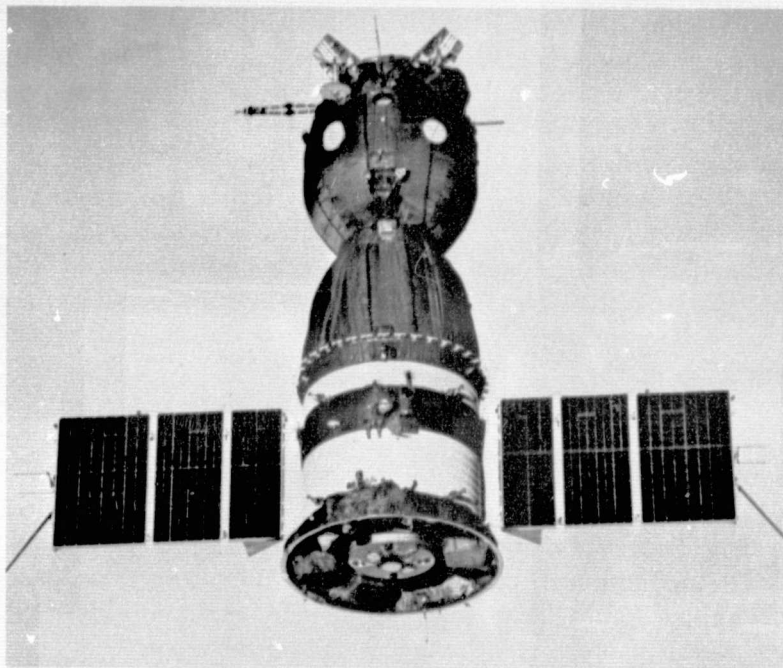
The two-gas atmosphere normally used in the Soyuz was about the same as the atmosphere on Earth at sea level—it consisted of a mixture of nitrogen and oxygen at a pressure of 1 kilogram per square centimeter (14.7 pounds per square inch).

The Apollo atmosphere was very different—it was made up of pure oxygen at a pressure of only 0.35 kilogram per square centimeter (3 pounds per square inch), which is only about one-third the pressure of the normal Earth atmosphere.

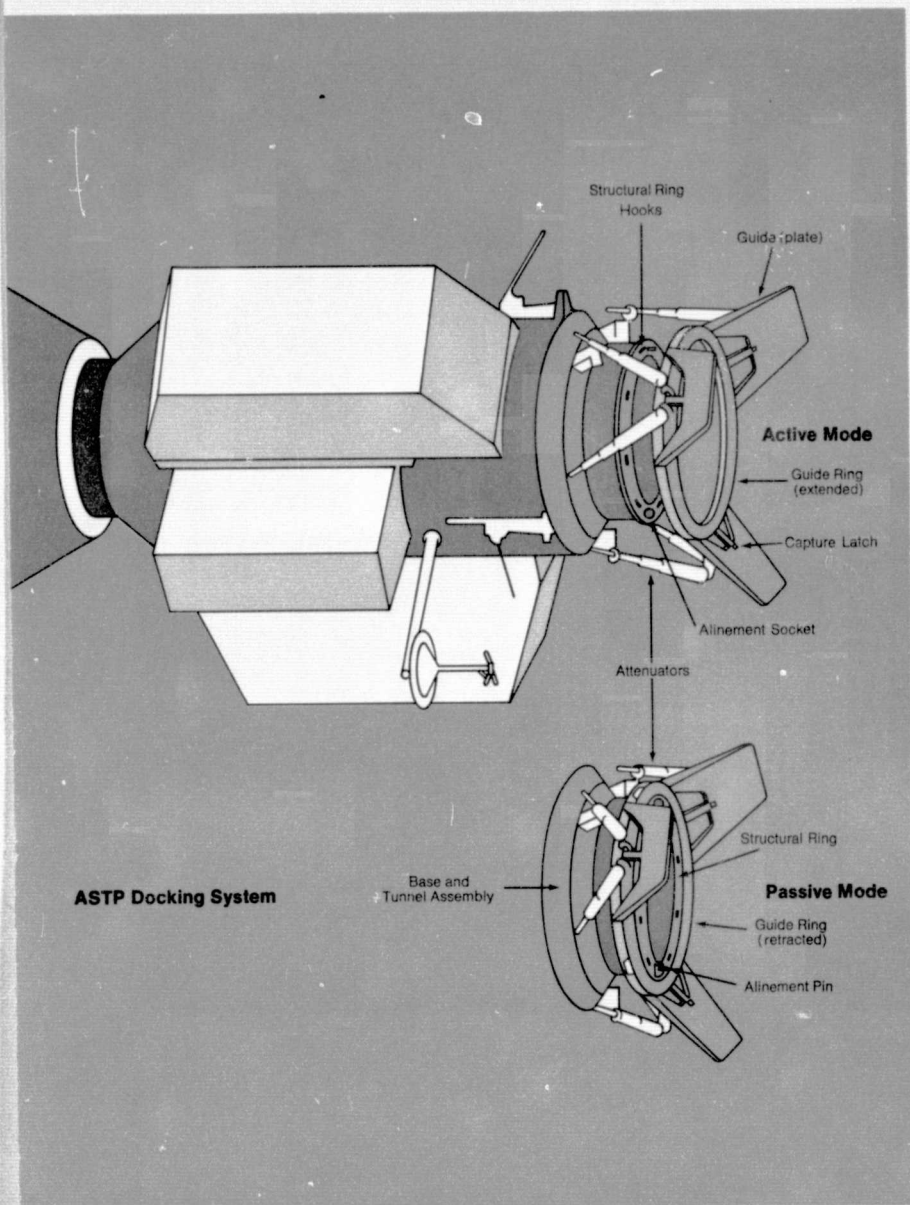
Such great pressure differences during the flight would have

Soyuz in space.

*American part of
docking system.*

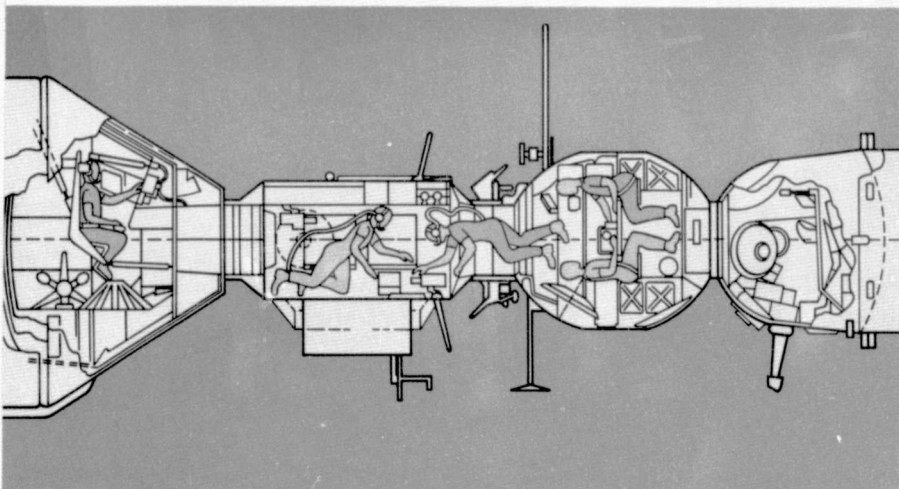
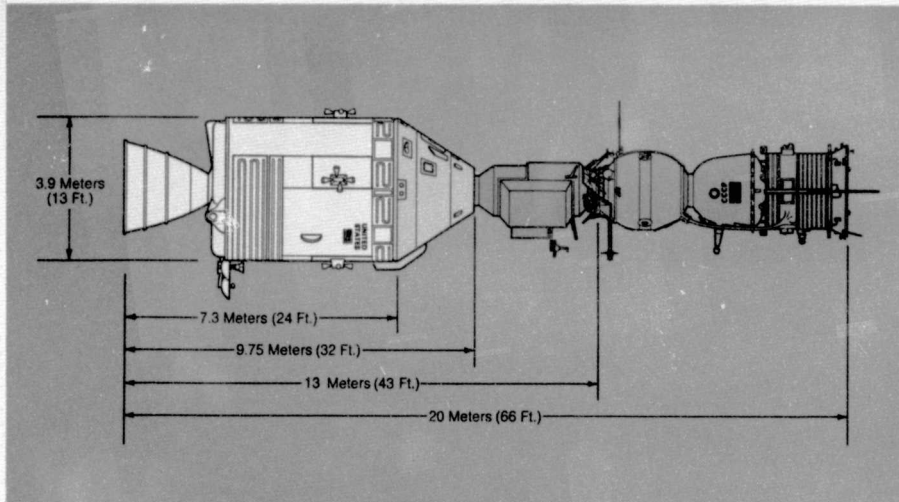


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*Dimensions of Apollo
Soyuz elements.*

*Cutaway of docked
spacecraft.*



required crew members to spend about two hours in the Docking Module during each transfer from the Soyuz to become accustomed to the Apollo atmosphere. Otherwise the men would have risked serious illness similar to "bends" experienced by deep-sea divers after rising too rapidly from ocean depths.

To shorten the time for a safe transfer, the Soviets reduced the atmospheric pressure inside Soyuz to 0.7 kilogram per square centimeter (10 pounds per square inch) and kept it at that lower level while docked. In this way, transfers were made without danger to the men and transfer operations in the Docking Module required only a few minutes.

The Apollo (without the Docking Module) was 12.6 meters (42 feet) long, 3.9 meters (13 feet) at its widest diameter, and weighed 12 731 kilograms (28 054 pounds).

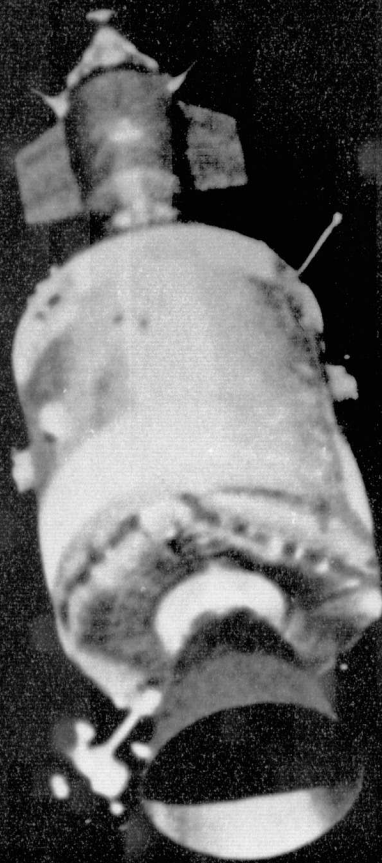
The Soyuz was 7.5 meters (25 feet) long, had a diameter of 2.72 meters (9 feet) at its widest circumference, and weighed 6800 kilograms (14 991 pounds).

Each craft consisted of three major compartments or "modules" attached end to end. At one end of the Apollo was the Service Module with the bell-shaped exhaust cone of the main propulsion system protruding into space. The Service Module was a cylinder 7.2 meters (24 feet) long and 3.85 meters (13 feet) in diameter that also contained supplies and equipment.

Attached to the Service Module's other end was the funnel-shaped 2.4-meter (8-foot) long Command Module in which the astronauts lived except when they were transferring to Soyuz or working in the Docking Module. The Command Module, which contained the spacecraft controls, was the only part of the Apollo that returned to Earth: the other modules were jettisoned to burn up from air friction as they plunged into the atmosphere.

The pointed end of the Command Module was attached to the Docking Module. The men crawled through a narrow tunnel to reach the Docking Module and then floated or crouched in it while working or opening the hatch into the spherical Orbital Module of the Soyuz.

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*Apollo and its Docking
Module photographed
from Soyuz as the
crews rendezvoused
in space.*

The hatchway and tunnel between the Apollo Docking Module and the Soyuz Orbital Module was ringed externally by the new docking mechanism in its hard-dock position.

The Orbital Module, used by the Soyuz crew for work and rest during the mission, was 2.5 meters (8.7 feet) long and had a diameter of 2.7 meters (9 feet).

Next came the Descent Module of the Soyuz—2.2 meters (7.2 feet) long—equipped with the main controls and couches for use by the crew during launch, descent, and landing. At its far end was the Instrument Module—2.3 meters (7.5 feet) long—containing subsystems for power, communications, propulsion, and other functions. Extending from opposite sides of the Instrument Module were two 8.37-meter (28-foot) winglike solar panels for converting sunshine to electricity for recharging the Soyuz batteries. In contrast, the Apollo was powered by fuel cells. Fuel cells generate electricity by chemical means and eliminate the necessity of frequently turning a spacecraft, or its solar panels, toward the Sun.

These two joined vehicles, the Apollo and the Soyuz—each with more than a dozen successful flights in space—were the flagships representing their nations for 1975's Apollo Soyuz Test Project.

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The Apollo Soyuz "universal" docking system was jointly defined in meetings between U.S. and Soviet specialists, then was independently developed and built by each nation to the agreed specifications.

The docking system on each spacecraft had three ring-shaped elements that functioned together—base assembly, structural ring, and guide ring.

Only the guide ring was movable. When retracted, it nestled beside and around the structural ring, a short distance forward of the base assembly. With the guide ring extended, its three petal-like guide plates and their capture latches were ready to "soft dock" with the retracted guide ring of the other spacecraft. Soft dock refers to the touching and preliminary latching of two spacecraft to keep them from drifting apart. The linkup is not sufficiently firm to permit the opening of connecting hatches or the transfer of men from one craft to the other.

In the Apollo Soyuz soft docking, guide ring met guide ring. As the tapered petal-like plates (tilted outward at a 45-degree angle) met and slid against each other, they induced a slight rolling motion to one or both spacecraft that ended when the bottom edges of each plate came together, abruptly providing proper clockwise (angular) alinement of each spacecraft. The gentle closing momentum, aided by the activation of spring-loaded capture latches on the guide plates, pulled the guide rings together so that their surfaces met snugly all the way around, thus providing the correct lateral alinement of each spacecraft.

With soft docking accomplished, the extended guide ring was retracted until the structural rings and mating surfaces of each spacecraft met in proper alinement and structural-ring hooks were engaged to provide the "hard dock." Hard dock refers to the final, firm attachment of two spacecraft, locking them virtually into a single vehicle. Proper alinement was facilitated by the mating of alinement pins and sockets mounted on the structural ring of each spacecraft. Concentric seals on the mating surfaces, when compressed by the structural latches, provided a pressure seal to the tunnel area between the spacecraft when it was pressurized for use as a passageway by the crew members.

Значение

The Meanings

At the NASA News Center near Houston two newsmen were chatting:

"Would Stafford have believed it if anyone had predicted when he became an astronaut 13 years ago that someday he would be in space showing the United States to a Soviet Air Force colonel at his side and that the colonel, in turn, would become Stafford's tour guide while the two were looking down on the Soviet Union?"

The two writers were sitting beside a loudspeaker carrying voice transmissions from the linked Apollo Soyuz spacecraft. At that very moment just such a travelog was going on in orbit.

Soviet Air Force Colonel Leonov was talking to Stafford while pointing out the sunlit plains of the Soviet Union below.

The newsmen's colleague did not answer the question. Instead he pointed to an overhead sign and said: "Would you have believed it if anyone had told you five years ago there would be a sign like this at an American space center?"

The upper half of the sign read "News Center" in English. The lower half said the same in Russian. Other signs at the news center were similarly printed in English and Russian.

It was a strange sight for veteran space reporters. The Houston news center had always been an international meeting place. But no press representatives from the Soviet Union had been there previously during a U.S. space flight. Now, among the 803 accredited Apollo Soyuz press representatives from 27 countries, 24 were from the Soviet Union.

Soviet and U.S.
reporters interview
Stafford and Leonov,
the two crew com-
manders, during press
day at Star City.
Stafford is at left on
dais, Leonov at right.

"Coffee" in Russian
and English at Houston
news center.



Cosmonauts Kubasov (left) and Leonov place wreathes on the graves of astronauts Grissom and Chaffee who died in the Apollo spacecraft fire at Cape Canaveral in January 1967. In the background are flight crew and mission support members.

"News Center" in Russian and English.

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Stafford (light coat and black hat) and Eugene A. Cernan (on his left), special assistant to the U.S. Technical Director of Apollo Soyuz, tour Moscow with other members of the Soviet and American technical teams. Americans were in Star City near Moscow for Soyuz

familiarization training. In background is Cathedral of the Intercession (St. Basil's) Museum.



Other U.S.S.R. citizens also were working at the Houston center. A room used for press briefings during Apollo Moon missions and the Skylab space station flights was designated as the "Soyuz Room" (with appropriate signs in English and Russian). Stationed in it were Soviet public information officers and interpreters (three men and three women) who answered queries from press representatives from around the globe.

Ten Soviet technical specialists who had been given training in Houston were in the Apollo Mission Control Building at Houston. They were there throughout the joint phase of the flight to explain any problems with the Soyuz to the American flight controllers and help smooth out any joint technical or operational problems.

Similarly, eight American specialists who had been trained in the Soviet Union were at Soyuz Mission Control in Kaliningrad to explain Apollo problems to Soviet flight controllers and to help coordinate joint operations during the flight.

In Moscow, American information officers were at a press center at the Intourist Hotel to serve press representatives from any country. About two dozen U.S. newsmen reported on flight events from the Soviet Union.

These were some of the numerous and readily noticeable differences the Apollo Soyuz Test Project brought to the space establishments of the United States and the Soviet Union.

There were other more subtle, less discernible changes.

Professor Konstantin D. Bushuyev, Soviet Technical Director for the project, when asked to describe the climate of the 44 working-group meetings that preceded the flight, replied, "In our joint work, there had been only one contradiction: Dr. (Glynn S.) Lunney (the U.S. Technical Director and Professor Bushuyev's American counterpart) drinks black coffee and I drink coffee with cream."

Charles W. Busch, who participated in many of the negotiations as Chief of Communications Operations Integration Plans

at the Johnson Space Center, recalled, "We discovered that on both sides we had sons who needed haircuts and kids who listened to too much loud music. We found we had things in common and we became friends."

Arnold Frutkin, NASA's Assistant Administrator for International Affairs, who participated in and observed the negotiations at close range, said: "There is a group of Soviets who now have a better sense of what Americans are like and a group of Americans who understand the Soviets better." He said this "beachhead of understanding can't help but be for the better."

Contacts between astronauts and cosmonauts were even closer than those between administrative and technical personnel. The U.S. and Soviet crews made several training trips to each other's country and spent many hours together in the relatively small area of "simulators" that resembled the spacecraft and the connecting Docking Module. Seated shoulder to shoulder, the men underwent "familiarization" with each other's spacecraft equipment and were trained in the procedures and proper actions for every conceivable emergency.

Besides the three U.S. astronauts and two Soviet cosmonauts designated as the "prime crew," three other astronauts and three sets of two cosmonauts each were trained as "backup crews." Another three astronauts were assigned as the U.S. "support crew." The backup crews were prepared to be launched if, for any reason, the prime crew members were unable to fly the mission. The backup crew members mingled in similarly close relationships during training, and the support crew (who assisted with training and other preparations but were not trained as flight stand-ins) also participated in many joint crew activities.

Beyond their closeness at work, the crews—and sometimes also the backup crews—spent good portions of their free time together. When the cosmonauts were in the United States for joint training, the astronauts took them sightseeing and to a variety of social events and introduced them to U.S. Government officials and to colleagues and friends. On their visit to the White House,

President Ford took both crews with him to a crab festival in nearby Virginia.

The spirit of the occasion when the American President ate at the same picnic table with the Apollo Soyuz crews from both nations—and the numerous other occasions when the crews shared meals—was captured by Leonov when he was asked in flight how he liked American food. The question came from the spacecraft communicator at Kaliningrad and referred to the American space food he was served while visiting inside Apollo.

"I like the way it is prepared," Leonov replied, "but, once again, I would like to say that space food is not the same food which is eaten by people on the Earth, . . . but, as an old philosopher says: 'The best part of a good dinner is not what you eat but with whom you eat.' Today I had dinner in the Apollo together with my very good friends Tom Stafford and Deke Slayton (Vance Brand and Valeriy Kubasov were eating together in the Soyuz) and that was the best part of my dinner."

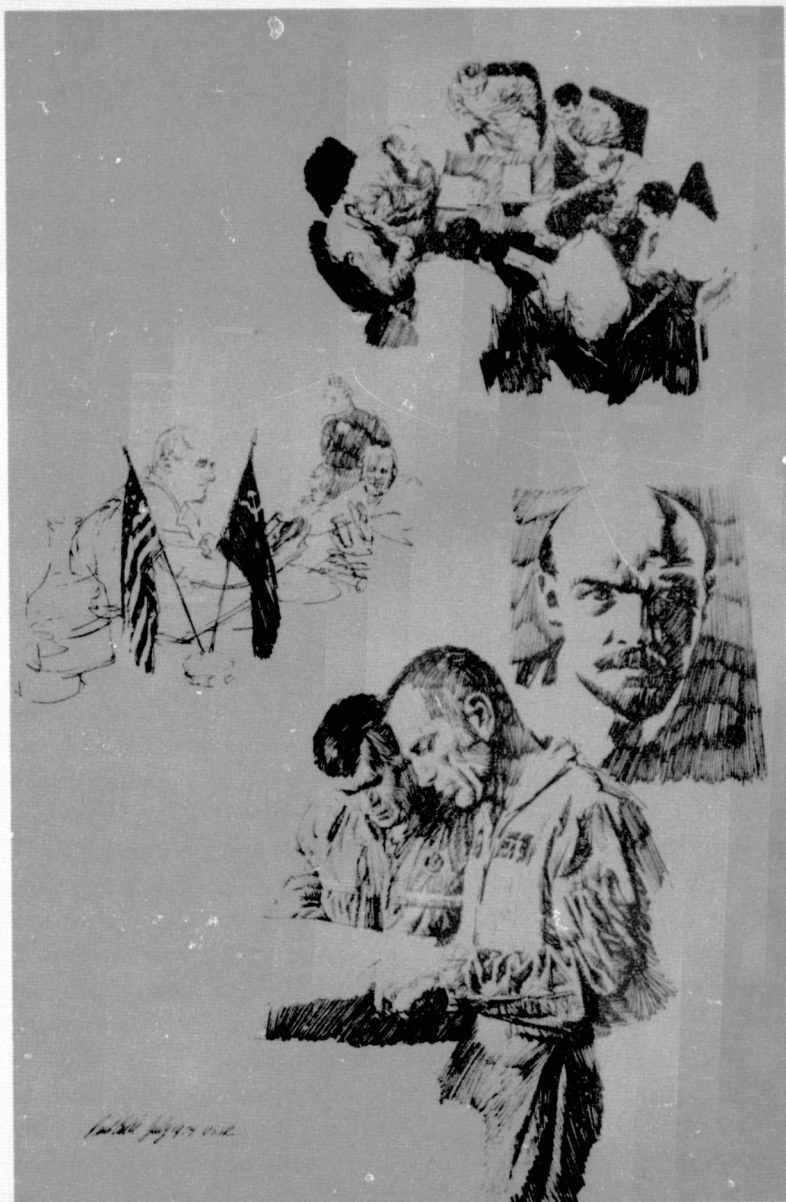
There were psychological and social as well as technical implications to be found in Apollo Soyuz.

"It is a pioneering venture of a different kind—pioneering in international cooperation," said Dr. George M. Low, NASA Deputy Administrator. "We are learning how to work with our chief competitor, how to cooperate on a most complex project where the final report card will be visible to all. We are opening the door for more cooperative efforts in the future."

Only a few weeks prior to the July 15 launch day, representatives of both nations discussed ways to retain the cooperative momentum gained from Apollo Soyuz. Agreement was reached to hold further talks regarding the specifics of possible future manned missions.

The compatible docking system demonstrated by Apollo Soyuz makes possible a variety of cooperative projects involving manned spacecraft from the U.S. and the U.S.S.R. Similar docking equipment might someday permit a U.S. Space Shuttle to dock with a Soviet space station such as Salyut. A standardized docking

Astronauts and cosmo-
nauts go over flight
plans in Star City.
(Sketch by Paul Calle.)



mechanism would be essential for Earth-orbiting space stations built, supplied, and staffed by two or more nations working together for common and global interests. With a common docking system, such a station could be built from modules manufactured in various countries and launched separately for assembly in orbit. Shared costs and facilities would bring substantial savings to each participating nation. Apollo Soyuz also showed that a standardized docking mechanism would lend itself to international rescue operations if a crew from any nation was stranded in orbit in a malfunctioning spacecraft and no spacecraft from its own country was ready to help the endangered crew.

Leaders of both nations, in messages to the Apollo Soyuz crews shortly after the two spacecraft docked in orbit, were looking toward the future.*

Declared Leonid I. Brezhnev, General Secretary of the Soviet Communist Party: "It could be said that the Soyuz Apollo is a prototype of future orbital space stations."

Said President Ford: "I am confident that the day is not far off when space missions made possible by this first joint effort will be more or less commonplace."

The Apollo Soyuz project introduced scientists and engineers from the United States to a Soviet program that had long been hidden from public view. American teams visited the Soviet launch site at the Baykonur Cosmodrome. As noted earlier, a NASA official and other representatives of the U.S. Government attended the Soyuz launch.

A large number of technical problems were unraveled by the joint working groups, with both sides contributing to the resolution of difficulties.

When American engineers and managers requested information about the Soyuz spacecraft to assure themselves about the safety of the American crew and the success of the joint flight, Soviet officials provided the necessary assistance. Still, to protect technological innovations in each nation's spacecraft, disclosures about manufacturing techniques and the internal workings of

* Full texts of messages in Table A, page 113.

advanced space equipment were carefully avoided. Even the U.S. and Soviet elements of the joint docking system were built independently, with NASA developing an electrohydraulic system while the Soviets built an electromechanical system for Soyuz. The two designs meshed perfectly in ground tests and proved themselves in flight because of the earlier American-Soviet agreement on system specifications.

Public information agreements negotiated before the mission led to significant changes in Soviet openness about the flight. For many years, the Soviet press made no report of preparations for space flights. The date and purpose of planned launches and even the names of crew members were kept secret until the spacecraft were in orbit. Even then, little substantial information about the purpose of a flight or its planned duration was provided to the public.

For Apollo Soyuz, however, the identities of the Soviet prime and backup crews were announced long in advance, the launch date was widely publicized, and minute-by-minute details of the joint flight plan were made known to the world press well in advance of launch. A lengthy press information kit, similar to those normally published by NASA for its flights, was prepared by the Soviets, printed in both Russian and English, and distributed to the world news media. A press center was set up in Moscow's Intourist Hotel and newsmen were invited to visit the cosmonaut training facility known as Star City and the Flight Control Center at Kaliningrad just prior to the flight.

The Soviets for the first time provided live television of the Soyuz launch and landing and from the Soyuz spacecraft. Detailed plans for much of the television coverage were agreed to in negotiations with NASA public affairs officials, although some coverage—including the Soyuz view of Apollo during docking—was lost due to a malfunction in the Soviet television system.

Soviet cosmonauts participated with the astronauts in a press conference from space and flew to the Moscow news center to meet with the press soon after their Soyuz landing.

Despite the substantial increase in information made available by the Soviets, Western journalists were disappointed by the refusal of Soviet officials to open the Baykonur Cosmodrome to news reporters wishing to report firsthand on the launch of the Soyuz. Despite pressure by U.S. correspondents and officials in Moscow, the launch site remained closed to the press. Newsmen watched the Soyuz liftoff by television at the press centers in Moscow, Houston, and Florida.

In the United States, more than 2000 news representatives from 27 countries were in Florida and Houston to cover the joint flight. Although 24 Soviet journalists were accredited to both the U.S. launch site and to Houston, none went to Florida for the Apollo liftoff.

The Apollo Soyuz flight proved to be one of the major world news events of 1975.

The story of the joint mission was carried on the front page of every major Soviet newspaper—covered more extensively, veteran observers noted, than the heavily reported summit visits. Soviet press criticism of the United States was muted during the joint flight and American correspondents found Soviet information officials unusually helpful in answering the many questions that arose during the mission.

Editorial comment in the world press was mixed. Many news analysts said the joint flight was solid evidence that the United States and the Soviet Union could work together on a difficult project requiring careful coordination. Some praised this as one of the first steps to a new world in which tensions might be significantly reduced as the two nations extended cooperation to expanded trade and other areas. Still other analysts noted, however, that basic conflicts between the two major powers remained unresolved. Remarking that detente had only slightly reduced military, political, and economic confrontations between the United States and the Soviet Union, a number of commentators argued that the joint space project might temporarily submerge underlying differences, but that events in space would not dictate policy on Earth.

A few papers criticized the joint project as a pointless display of cooperation without real benefits. West Berlin's *Spandauer Volksblatt* complained that the "mammoth project is nothing but a glittering soap bubble"; while Manfred Beer of Bonn's *Neue Rheinische Zeitung* commented that "persistent negotiations and understandings are what we need—not acrobatics in space."

In France, Alain Duhamel of Inter-Radio said, "Positive consequences can already be seen—access of U.S.S.R. TV viewers to the launching of Soyuz and, for Soviet journalists, a beginning of information about space." In Copenhagen, *Jyllands-Posten* said Apollo Soyuz "prompts reflection on how much the world's two biggest superpowers could achieve if they agreed to mobilize their strength and technology in joint service of more close-to-Earth causes."

London's *Sun*, regretting the project's cost to the United States and the Soviet Union, said: "It was the world's most expensive handshake, but it will not have cost a dollar or ruble too much if it is a handclasp for peace."

"The end of the space race," proclaimed Bogota's *El Tiempo*.

"A new era of cooperation instead of competition," editorialized Tokyo's *Asahi*.

"Impressive evidence of goodwill of East and West," said *Volks gazet* in Brussels.

"The most dramatic product of detente," announced New Delhi's *All-India Radio*.

Kenya's *Daily Nation* said the international mission would "show the world that nations can still transcend ideological and other differences in common pursuit of the highest aspirations of mankind."

The *Houston Chronicle*, in an editorial on July 23, 1975, two days after the Soyuz landing and one day before the Apollo splashdown, concluded that there is value in cooperation such as exhibited in Apollo Soyuz (and in the general relaxation of tensions) "if not for what it is now, then for what it might become."

Newspapers worldwide
report on the joint
flight.

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The idea that much of the full diplomatic and psychological impact of Apollo Soyuz still lies ahead also was expressed by NASA Administrator James C. Fletcher in a statement issued immediately after the Apollo splashdown.

"By going into space together we have shown a sometimes skeptical world that perhaps there is a real chance for world unity. It is my belief that we should hang onto this chance and expand our efforts into more extensive cooperation both on Earth and in space."

On that theme, Dr. Low said: "Nations that work together to reach the stars are that much less likely to descend together into the depths of war and desolation."

Perhaps the significance of the Apollo Soyuz was expressed best by astronaut Karol Bobko, a member of the U.S. support crew and one of the project's spacecraft communicators at the Apollo Control Center in Houston. As is customary for the flight director and "capcom" (capsule communicator) at the end of each work shift, Bobko reported briefly to the press about activities in Mission Control.

At the 7 a.m. briefing, July 24—ending his last tour of duty as capcom—Bobko talked to the assembled reporters and writers.

"When I first came on the Apollo Soyuz program I think that I underrated the difficulties that would occur because of the language [difference] and because of the different technologies. And after we got into the program a little bit, it became obvious that this was going to be a difficult thing to integrate.

"But I think that everybody really has been pleased with the way that the control centers, the crews, . . . all things have worked together to come out with a flawless mission. The crews have been able to communicate well; the spacecraft have worked well. We proved that it is completely feasible to have joint missions."

Then Bobko recalled a question asked earlier by a reporter and noted that in one of the joint scientific experiments the astronauts and cosmonauts carried out together during the mission, they

obtained data on the makeup of the Earth's atmosphere through a process known as ultraviolet absorption.

"I was a little surprised," continued Bobko, "that one of the questions asked the other day was 'how long do you think it will be before we'll [Soviets and Americans] start to explore a planet?' And I thought to myself that here we are—we have started together to explore a planet, and that planet that we started to explore together is the planet Earth."



ORIGINAL PAGE IS
OF POOR QUALITY

The Scientific Experiments

- A new kind of Apollo telescope took its first look at the heavens from above the Earth's atmosphere. What it saw astounded astronomers. Searching for "extreme-ultraviolet" radiation, it found the first extreme-ultraviolet sources outside our solar system, and, by so doing, located stars the existence of which had been theorized but which, some scientists had believed, could never be found. One of these stars turned out to be the hottest known "white dwarf star." A white dwarf is made up of matter so heavy that a pebble could weigh a ton. The Apollo discoveries may mark the birth of a new branch of astronomy.

- Another exciting discovery came from a space-dependent branch of astronomy, the orbital detection of X-ray emissions from stars. An Apollo detector revealed the existence of the first known pulsar outside our Milky Way galaxy. Approximately 200 000 light-years from the Milky Way, it is the most luminous pulsar known to astronomers.

- In weightlessness, an Apollo electrical machine separated different types of human and animal cells that are difficult or impossible to sort on Earth because of the pull of gravity. Scientists say the process—called "electrophoresis"—could become an important future space activity for medical research and for isolating disease-fighting or life-saving biological material.

- From their orbital vantage point, astronauts looked on the land and oceans and made observations requiring skills and judg-

ments no machine can duplicate. Using color charts, they informed scientists about the precise hues of blue of various portions of the oceans and the exact shadings of tan and brown of deserts. Scientists are determining to what extent this information can help in economic development in some aspects of social planning.

As these four examples indicate, scientists took full advantage of the opportunity the Apollo Soyuz mission offered for research by manned orbiting spacecraft. The Apollo carried equipment for 23 science and technology experiments; the Soyuz was equipped for six. These were conducted by each crew independently.

In addition, the two craft were outfitted to carry out five joint experiments requiring simultaneous cooperative participation by both crews and craft.

The independent Soyuz experiments consisted of three each in the fields of astrophysics (the makeup and activities of celestial bodies) and biology.

The independent Apollo experiments were in three categories: (1) space sciences—observations of the Earth and the universe from above the Earth's atmosphere, (2) life sciences—studies of the influence on living entities of prolonged weightlessness and of other space conditions, and (3) applications experiments—investigations on how space technology and space conditions (such as prolonged weightlessness) can be put to use for improving living conditions on Earth.

Of the five joint experiments, three were carried out while the two craft were linked together, and the remaining two took place after Apollo and Soyuz had undocked on the flight's fifth day, Saturday, July 19, 1975.

In a joint U.S.-U.S.S.R. experiment, the American crew's commander, Thomas P. Stafford, using Apollo controls and thrusters, turned the still docked Apollo Soyuz craft so that the Apollo end pointed toward the center of the Sun. After undocking, he backed the Apollo away on a straight line until the distance between the two spacecraft was 200 meters (650 feet). At that distance the circular outline of the Apollo blocked out the brilliant center of

the Sun and gave the Soyuz crew a chance to photograph and view the solar corona that extends far into space.

In effect, the Apollo created an eclipse of the Sun for the solar observation instruments on board Soyuz. The solar corona ordinarily cannot be observed because its radiations are overwhelmed by the brightness of the Sun's center.

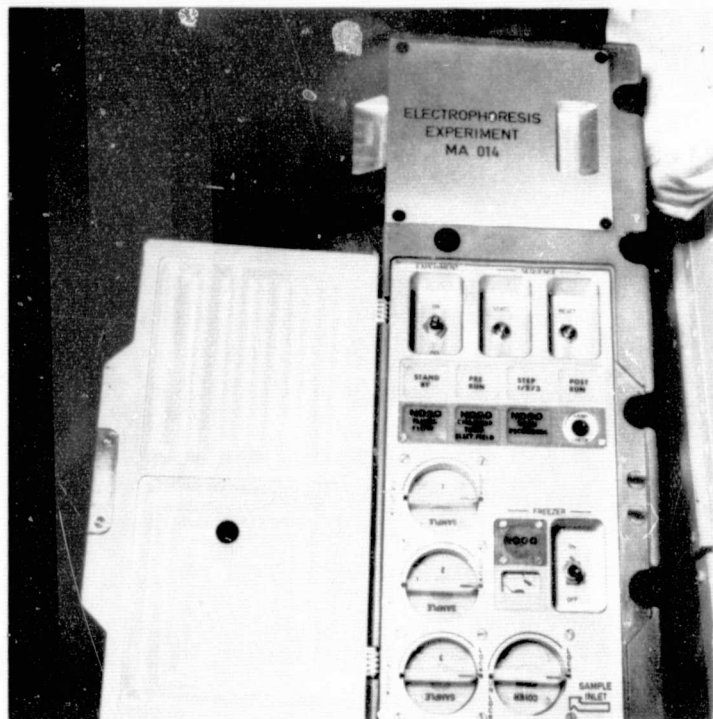
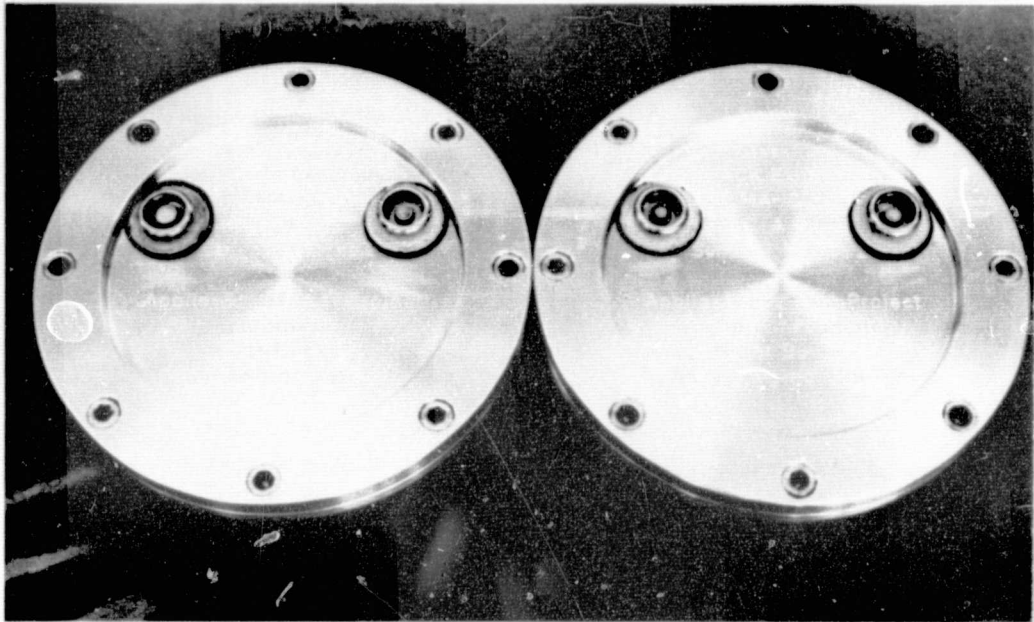
The pictures and observations by Soyuz from above the Earth's atmosphere will be made available to researchers. From pictures of this sort, scientists hope to gain a better understanding of the Sun's prodigious energy-generating abilities and its profound influence on the weather and on radio communications and other aspects of life on Earth.

In the other joint postdocking experiment, one of several mirror-like reflectors on the Soyuz bounced back light emitted by an instrument aboard the Apollo. The invisible ultraviolet light was sent out while the two spacecraft were 150 meters (500 feet), 500 meters (1670 feet), and 1000 meters (3340 feet) apart. A sensing device on the Apollo determined how much of the light returned and how much was lost on the round trip. Scientists can tell from the amount of light returned how many oxygen and nitrogen atoms were floating in space above the Earth at the altitudes of the Apollo Soyuz orbit. This knowledge is needed for a better understanding of the Earth's entire complex atmospheric system so that scientists can monitor conditions to detect possible adverse changes caused by manmade pollution.

The third joint experiment was an investigation of how space flight changes the ability of microbes to infect humans, and how space flight alters the ability of humans to resist infection. In earlier space flights scientists had learned that microbes transfer from one crew member to another just as they do between people in close contact on Earth. Also, microbes transfer to the spacecraft and its components. The earlier flights also had taught that in the isolated world of a spacecraft, the varieties of microbes decline but the numbers of each surviving type of microbe increase sharply.

*The two containers
housing the Apollo
Biostack experiment.*

*German electrophoresis
experiment package
flown on Apollo.*



In the past, crews and spacecraft always had been launched from the same location, but the Apollo Soyuz men and spacecraft started from widely separated launch points with, presumably, very different strains of microbes aboard. The crew members swabbed their skin several times before, during, and after the flight, and they also took swabbings of their spacecraft walls, floors, and ceilings. These swabbings were stored in sealed containers aboard the spacecraft and later were analyzed in laboratories to learn about microbe migrations. To learn about changes in crew members' immunological resistance, blood samples were taken of crew members before and after the flight.

In the fourth joint experiment, the crews observed and photographed colonies of fungi once every 12 hours to note any changes in growth patterns. The purpose of the experiment was to investigate the effects of cosmic radiation on several types of living cells. Changes in growth rhythms and in certain properties of the fungus cells could give clues to possible cosmic radiation effects on human cells during prolonged space flight.

Shortly before the Apollo and Soyuz separated, the crews exchanged two dishes of fungi so that each crew brought back one dish from the other country in addition to one dish from its own. In this way, scientists on Earth could note any differences in growth patterns that might have occurred because of the different environments of the fungi before and after the flight. Comparisons also were made with fungi of the same species that had remained on Earth.

In the fifth joint experiment, the Soyuz crew gave the Americans three small cylinders containing metals that cannot be uniformly mixed on the ground because of the Earth's gravity. In their molten state on Earth, the heavier metals settle to the bottom before the mixture can be cooled and solidified. The astronauts loaded the cylinder in an electric furnace in the Docking Module and after heating, melting, and cooling in weightlessness, returned the test samples to the cosmonauts for analysis by Soviet scientists after return to Earth.

The furnace also was used by the astronauts during the solo phase of the mission for a number of experiments dependent on the prolonged weightlessness available only in space. The astronauts used the furnace to grow, by vapor condensation, crystals of greater purity than it is possible to produce on Earth. Such crystals are expected to perform better than Earth-grown specimens in electronic devices and, perhaps, make possible new kinds of devices.

These experiments, an extension of studies made with less sophisticated furnaces on U.S. Apollo and Skylab flights, may be forerunners of small space factories in Earth orbit for the manufacture of special alloys and other materials with electrical and structural characteristics unobtainable on the Earth. Some engineers foresee the eventual production in space of materials never seen on the Earth, possibly alloys lighter than cork but stronger than steel.

As mentioned briefly at the start of this chapter, the U.S. astronauts made news when they looked around the sky in a way no one had ever done and detected the first extreme-ultraviolet radiation sources outside our solar system. Based on the observations, four such sources were positively confirmed to exist, and analysis of the strongest source led to the discovery of the hottest known white dwarf star.

The experiment, designed by astronomers of the University of California at Berkeley, used a telescope built into the side of the Apollo spacecraft. Because extreme-ultraviolet radiation cannot penetrate the Earth's atmosphere and is readily absorbed by gas clouds believed to be spread throughout the universe, many astronomers thought this radiation never could be detected and that any stars emitting it would remain unknown. The California astronomers, however, theorized that the gas was distributed so unevenly throughout the universe that there could exist "holes" in these clouds through which extreme-ultraviolet radiation could be observed from above Earth's atmosphere.

Thanks to the Apollo telescope, the extreme-ultraviolet region

of the electromagnetic spectrum finally has given way to the onslaught of science. The astronauts' investigations may give birth to a new branch of astronomy—extreme-ultraviolet astronomy—that could help lead to a better understanding of the beginning, present status, and destiny of the universe.

Another new space-spawned branch of astronomy was advanced, as indicated earlier, through an instrument on Apollo for detecting and recording X-ray emissions from stars. These emissions, like extreme-ultraviolet radiations, are screened out by the Earth's atmosphere and can be observed only from space.

The astronauts, after circumventing a technical malfunction in the equipment, succeeded in mapping X-ray sources throughout the Milky Way galaxy. Scientists expect the new information will provide clues to the makeup of stars and to evolutionary processes at work in the universe—particularly how X-ray-emitting stars generate energy. Understanding of similar processes in the Sun, gained earlier in this century, contributed to the development of ways to use nuclear energy.

Analysis of the X-ray data revealed the existence of the first-known "pulsar" outside our Milky Way galaxy. A pulsar is a star that makes its presence known through emissions of radio signals only a fraction of a second or several seconds apart, thus creating a pulsating "on-off-on" effect at the receiving radio telescope.

The Apollo-discovered pulsar is one of two stars rotating around each other (called a "binary system" of stars) in the Small Magellanic Cloud, a small galaxy 200,000 light-years from the Milky Way. Actually, a distance of 200,000 light-years makes it one of the close celestial neighbors of the Milky Way, by the standards of distances in the universe. The pulsar is 10 times brighter than any other discovered so far, a fact that makes it particularly valuable for study by astronomers trying to learn about the life cycles and characteristics of stars.

However, the object in the universe that received most of the attention from the astronauts' scientific instruments was the planet Earth.

The astronauts had been assigned 110 tasks calling for close examination by them from their high altitude of specific aspects of oceans, lakes, deserts, geological features, snow accumulations in mountains, storms and other cloud formations, and evidence of water pollution. Nearly all the assigned tasks were completed. Several assigned sightings could not be made because of obstructing clouds.

While the astronauts were making these observations from space, coordinated investigations were made simultaneously by scientists in six field parties on the ground, on nine ships at sea, and in nine aircraft flights. Forty individual investigators and groups participated in these experiments in the United States as did representatives from nine countries on five continents.

While orbiting above Algeria, Egypt, and the Arabian peninsula, the astronauts noted the precise color shadings of the desert sands (with the help of color charts especially prepared for use on board Apollo). Scientists say the sands of "old" deserts are more reddish (because of oxidation of metals contained in them) than the sands of newly formed deserts. Through color mapping of deserts the scientists expect to chart and predict the movement and growth of deserts that have been adversely affecting the population of some of these regions.

Using their color charts the astronauts pinpointed shades of blue of different parts of the ocean to help chart currents, pollution, and the growth of micro-organisms such as the "red tide" near Boothbay Harbor, Maine. There, congregations of poisonous organisms have killed large quantities of fish, severely interfered with the shellfish industry, and brought on food poisoning through fish contaminated by the organisms.

In the other Earth observations, the astronauts examined volcanoes; shoreline erosion; iceberg movements; sediments in the river deltas; and vegetation patterns in Africa, Europe, Central and South America, Asia, Australia, and New Zealand. These observations were aimed at better management of natural resources and the prediction and monitoring of natural hazards.

In two experiments the astronauts operated electrical apparatus designed to separate mixtures of living cells through a process called electrophoresis. In these experiments sample mixtures of human cells, and also mixtures of animal cells, were sorted into types by taking advantage of differences in electrical characteristics at the surface of each kind of cell.

The process has already been widely used on Earth to segregate water-soluble materials, but has not worked well with relatively large particles such as cells because of disturbances caused by the pull of gravity. Scientists theorized that these disturbances can be avoided by taking the apparatus into orbit where the mixtures are weightless. Although electrophoresis was demonstrated during Apollo Moon flights, the Apollo Soyuz experiment was the first separation of live biologic materials in space.

Electrophoresis in space is expected to lend itself to the sorting of natural mixtures of cells according to their types and functions. When this technique is fully developed, it may become valuable in medical research and the treatment of patients. For example, the Apollo Soyuz astronauts performed separation experiments on three main types of cells with obvious medical implications: lymphocytes, bone marrow, and kidney.

Lymphocytes are cells that fight infections in the body and create immunity to diseases.

Bone marrow cells include cells responsible for producing red blood cells, and the astronauts sought to isolate this type from the others.

Kidney cells have among them cells that produce urokinase, an enzyme that removes blood clots from veins and arteries. The experiment resulted in concentrations of urokinase-producing cells. Research is continuing on whether such concentrated cultures of these cells can increase the world supply of urokinase, which is presently scarce. Its possible importance is emphasized by about 300 000 patients each year in the United States with blood clot disorders of which about 50 000 are fatal.

This experiment gave birth to two spinoff discoveries even before it was placed aboard the Apollo. These strokes of good fortune occurred during the development of the experiment. In their preflight research supporting the experiment, scientists at the State University of New York, Buffalo, New York, discovered an antibody with which they can perform immunological tests to distinguish between certain types of lymphocytes. In addition, the scientists discovered that the freezing medium that preserved the lymphocyte samples could also preserve granulocyte preparations that could be used in the management of certain kinds of leukemia cases.

One electrophoresis experiment was designed and analyzed by the Max Planck Institute for Biochemistry in Munich, Germany. The other was developed by the NASA Marshall Space Flight Center in Huntsville, Alabama, in cooperation with an investigative team drawn from government, industry, and universities.

The Apollo experiments with the electrophoresis apparatus, like those with the electric furnace, may eventually lead to orbiting factories manufacturing products for sale on Earth labeled "made in space."

The astronauts also performed, under weightless conditions, five science demonstrations from which schoolchildren are expected to learn by trying to duplicate them in Earth gravity conditions. The demonstrations were meant to establish how some basic physical principles work when they are not affected by gravity.

The first Apollo Soyuz science demonstration dealt with the behavior of foams in weightlessness. Chemicals were mixed and then shaken to create a foamy blend of gas and liquid. Without the pull of gravity, the foam remained very stable. It did not experience the separation actions—the settling of liquid or the bubbling of gas—that occur on Earth. This foam technique could make possible the manufacture in space of new metal or plastic products having improved structural and other physical and chemical characteristics impossible to achieve on Earth.

The second demonstration showed how liquids spread themselves over irregular and smooth solid surfaces in weightlessness. Oil was placed on a plastic surface. On Earth, a liquid spreads along a solid surface only when the flow is horizontal or downward. In space, the liquid spreads evenly in every direction regardless of how the solid surface is textured or oriented.

The third demonstration showed how liquids travel on wicks—such as used in oil lamps—under weightless conditions. On Earth, liquids move along wicks, even vertically, because of capillary attraction, the adhesion between molecules of the liquid and the wick. However, gravity restricts the flow, even horizontally, and puts a limit on how far the liquid can travel vertically. In space, the liquid travels smoothly and without limit along the wick in whatever position the wick is placed.

In the fourth demonstration, the astronauts revolved two spheres attached to each other by a rod. With the rod substituting for the absent gravitational attraction, the spheres continued to revolve around their mutual center of mass, becoming miniature Sun-planet or Earth-Moon systems. When two spheres of like weight (mass) were attached, the point about which they revolved was midway along the rod. When two spheres of unlike weight revolved, the pivot point shifted to a position on the rod nearer the sphere with the greatest weight.

The fifth demonstration dealt with the physics of rapidly spinning, unattached objects. The astronauts twirled and released a piece of metal shaped like a book. When the object was spinning freely about its shortest axis (across the thickness of the book), the rotation was uniform and stable. The same was true when the astronauts spun the metal object about its longest axis (from top to bottom of the book). But when the object was spun about its intermediate axis (across the width of the book, from the bound side to the opening edge), the rotation became irregular and the book-shaped metal began to tumble.

The demonstration illustrated that spinning a body about the axis of either the maximum or minimum moment of inertia (the

longest and shortest axes) results in stable, uniform rotation. But when an attempt is made, no matter how carefully, to spin an object about its axis of intermediate moment of inertia, the rotation becomes nonuniform and flip-flopping occurs.

The astronauts recorded all these demonstrations on film that was made available to schools for showing.

The Soyuz astrophysics experiments included photography of the Earth's horizon to analyze layers of the atmosphere, to detect aerosol content in the atmosphere, and to observe the Sun's outer region (the corona) by photographing it during its emergence from behind the Earth's horizon.

The Soyuz biological experiments included observations of the development of fertilized fish eggs, the growth of micro-organisms, and genetic changes in algae to determine the influence of space conditions on living systems.

For the scientists who designed and received the results of the experiments, the Apollo Soyuz Test Project represented a welcome research bonus during a period in which the United States could offer them no other comparable manned mission for several years.

Manned spacecraft can accommodate a wide spectrum of investigations because they are relatively spacious and have larger weight-carrying capacities than unmanned craft, which are usually compact, light, and dedicated to only one area of scientific interest. Another advantage is that crews can adjust research instruments and add their own observations and judgments.

The last opportunity for scientists to use a U.S. manned spacecraft was Skylab, an experimental space station. The largest spacecraft ever launched, the 77-metric-ton (85-ton) Skylab was inhabited alternately by three crews of three astronauts each for a total of nearly six months over a nine-month period from May 1973 to February 1974.

The next opportunity for scientists to place research equipment aboard a U.S. manned spacecraft will not come until the Space Shuttle makes its first orbital flights beginning late in 1979.

Члены экипажей

The Men

From one viewpoint, the Apollo Soyuz Test Project was a triumph for middle age. All five crew members were over 40. All were married and fathers of from one to four children.

The commander of the three-man Apollo crew, Thomas P. Stafford, 44, became one of four Americans to have been in space on four separate flights. On three earlier space flights, Stafford had lived in space for a total of 290 hours and 15 minutes—equal to more than 12 days—and he was considered to be the world's leading expert on the two key maneuvers required for bringing the Apollo Soyuz together in space: rendezvous and docking (formation flight and linking of orbiting spacecraft). Stafford, a brigadier general in the U.S. Air Force, had been an astronaut since September 1962 and had piloted jetplanes for more than 5000 hours. He was promoted to major general after Apollo Soyuz.

On his first space flight in December 15, 1965, Stafford and former astronaut Walter M. Schirra accomplished history's first rendezvous of manned spacecraft when they maneuvered their Gemini 6 to within 30 centimeters (a foot) of the orbiting Gemini 7, which also carried two astronauts. The 15-orbit flight lasted 26 hours.

On his second space flight, the 44-orbit, three-day Gemini 9 mission in June 1966, Stafford, as commander, and astronaut Eugene A. Cernan (later a deputy to the Apollo Soyuz American Technical Director) steered their craft into formation flight with

*Crews with docked
Apollo and Soyuz
model. Left to right
are Slayton, Brand, and
Kubasov, seated, and
Stafford and Leonov,
standing.*



an orbiting unmanned experimental vehicle in a test of rendezvous procedures.

Stafford's third space flight was as commander of the eight-day Apollo 10 mission in May 1969. His crew included Cernan and John W. Young. They circled the Moon 31 times, and Stafford and Cernan, in a dress rehearsal for the coming Apollo 11 lunar landing, rode their Lunar Module down to about 15 kilometers (9.4 miles) above the lunar surface. This was the closest approach human beings had ever made to the Moon. Then, the crew completed the first rendezvous and docking of manned spacecraft in Moon orbit when they reconnected their Lunar Module to the Command Module.

After his three missions, Stafford served for two years as Chief of the Astronaut Office and, from June 1971, as Deputy Director of Flight Crew Operations in charge of astronaut activities at the Lyndon B. Johnson Space Center.

Stafford's companions on Apollo Soyuz, Vance DeVoe Brand, 44, and Donald K. ("Deke") Slayton, 51, had never flown in space. They became the 76th and 77th persons, the 42d and 43d Americans, to fly in space.

Brand, a former Navy aviator and civilian test pilot and flight test engineer, had been an astronaut since April 1966. He trained as a backup for the Apollo 15 Moon flight crew in 1971 and for Skylab (space station) crews in 1973.

For Slayton, who became the oldest person ever to fly in space, membership on the crew represented a personal victory over adversity.

Slayton was the last active astronaut of the "Original Seven," the seven men selected in April 1959 as the first U.S. astronauts. Until Apollo Soyuz, he was the only member of that original group never to have flown in space.

Early in the space program Slayton had been selected to become the fourth American to fly in space as pilot of a three-orbit mission in the one-man Mercury capsule in May 1962. He was replaced in that assignment (by astronaut M. Scott Carpenter)

when physicians discovered that Slayton often developed irregular heart muscle movements during training. In almost any other occupation the condition would have made little difference, but for Slayton it meant disqualification for space flight status.

He took on desk jobs—first as Coordinator of Astronaut Activities and then as Director of Flight Crew Operations at the Johnson Center—but doggedly tried to get back into the astronaut pool from which space flight crews were selected.

Because of his insistence, space physicians began treating him with medications that stopped the irregularities. Eventually they did not recur even without the medication. On Slayton's request he was given extensive reexaminations. After a complete reevaluation of his condition, he was restored to flight status in March 1972, exactly 10 years after he had lost that status. He subsequently was assigned to the Apollo Soyuz crew.

The commander of the two-man Soyuz crew, Soviet Air Force Colonel Aleksey Arkhipovich Leonov, 41, a native of Listvyanka, Alta Kray, had been a cosmonaut since 1960. He was the first man to take a "walk in space" when he stepped from the hatch of Voskhod 2 in March 1965 for five minutes of "extravehicular activity" during the 17-orbit, 26-hour Earth orbital mission. It was the world's 14th and the Soviet Union's eighth manned space flight. Shortly after returning from the Apollo Soyuz flight, Leonov was promoted to the position of one-star general in the Soviet Air Force.

His flight engineer in the Soyuz was Valeriy Nikolayevich Kubasov, 40, who was graduated as a mechanical engineer for aircraft building from the Moscow Aviation School in 1958 and also earned a master of science degree before becoming a cosmonaut in 1967. He was the flight engineer on the 75-orbit, five-day Soyuz 6 mission in October 1969. Soyuz 6 participated with Soyuz 7 and 8 in the first space flight in history involving seven men and three manned spacecraft in orbit simultaneously. The crews steered their craft in a variety of formation flight patterns using manual control techniques that could prove helpful in the

future when one spacecraft might be needed to help another in emergencies.

On that flight, Kubasov executed a series of experiments on the behavior of materials in space that included the first welding of metals under conditions of weightlessness.

Throughout the Apollo Soyuz flight, two other Soviet cosmonauts were living aboard a Salyut space station on a two-month research mission unrelated to the international flight—but they raised to seven the total number of men simultaneously in orbit.

Памятные подарки

The Mementos

American astronauts and Soviet cosmonauts were sitting close to each other in their small spacecraft exchanging flags, medallions, plaques, and tree seeds and signing certificates.

It was a scene new to television. The astronauts and cosmonauts of Apollo Soyuz were in that initial part of the flight plan that called for "symbolic activities." Some newsmen referred to them as "diplomatic experiments" in contrast to the scientific experiments conducted during the flight. Others called the event a "summit in orbit" because it involved the highest levels of government in personal statements to the astronauts and cosmonauts from President Ford and Soviet Communist Party Secretary Brezhnev.

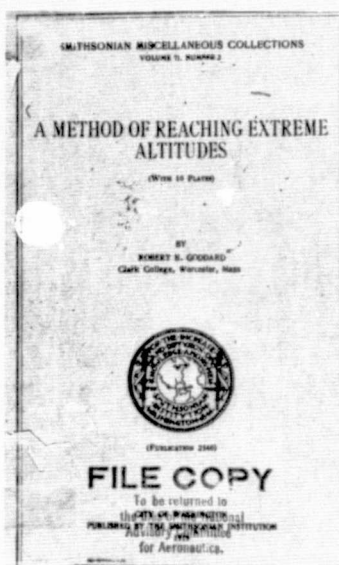
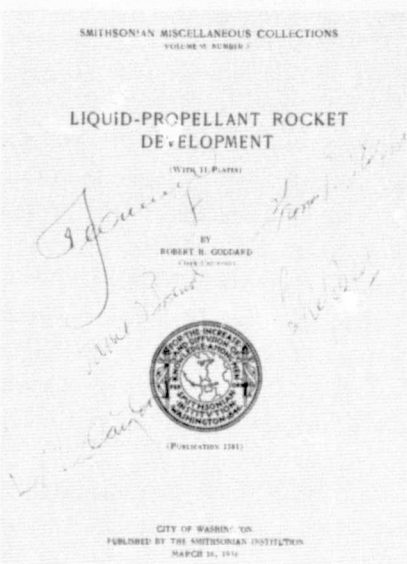
The Americans gave the cosmonauts five small U.S. flags 20 by 30 centimeters (8 by 12 inches) and received from the cosmonauts five small U.S.S.R. flags 20.5 by 41 centimeters (8.2 by 16.4 inches). These national flags were meant to symbolize the contributions made to the flight by citizens of the two nations.

Also aboard the spacecraft were some flags not for exchange but for safekeeping by each nation as remembrances of the flight. The Apollo carried one large U.S. flag 90 centimeters by 1.5 meters (3 by 5 feet) and five small U.S. flags 20 by 30 centimeters (8 by 12 inches).

The Soyuz carried along a large U.S.S.R. flag 90 centimeters by 1.8 meters (3 by 6 feet) and five small U.S.S.R. flags 20.5 by 41 centimeters (8.2 inches by 16.4 inches).

Apollo ceremonial items given to Soyuz crew at meeting in space: sectionalized commemorative plaque, box of tree seeds, American and Soviet flags (10 of each), and docking certificates. The Soviet and American crews exchanged items in space.

Taken into orbit to be autographed by the five crewmen were these two publications by U.S. rocket pioneer Dr. Robert H. Goddard. The autographed reports were delivered to the National Air and Space Museum of the Smithsonian Institution.



Closeup of genetically superior white spruce seeds presented by Apollo to Soyuz crewmen after docking. The seeds were intended to create an acre of fast-growing, exceptionally tall trees able to thrive in the Moscow climate.



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The cosmonauts gave to the Americans a United Nations flag that had been launched with them aboard the Soyuz. Returned to Earth aboard the Apollo, it later was presented to the United Nations by the five crew members.

Aboard each spacecraft were two halves of commemorative plaques and medallions. The crews joined the halves into complete units and each crew carried back to Earth one plaque and one medallion.

The crews also carried with them six copies (three in English and three in Russian) of the agreement signed by their national leaders on May 24, 1972, which led to the joint flight and also committed the two nations to other cooperation including exchange of information on space meteorology, biology, medicine, and the environment.

The most utilitarian items of exchange were two containers filled with tree seeds especially selected by each nation for their suitability to the climates of the recipient nation. The seeds were meant for planting about an acre of trees as a living monument to the Apollo Soyuz flight and the spirit it symbolized.

The certificates that the crews signed were prepared for the Fédération Aéronautique Internationale, which has certified world records in air and space achievements since 1905. Signing were astronauts Thomas P. Stafford and Donald K. ("Deke") Slayton and cosmonauts Aleksey A. Leonov and Valeriy N. Kubasov in the Soyuz on Thursday, July 17, 1975. The certificates were signed the next day by astronaut Vance D. Brand when he visited the Soyuz. This was a necessary step to enter the Apollo Soyuz flight officially on the international record books as a historic "first."

Also placed aboard the two spacecraft and autographed in flight by the five crew members were three works of the Russian rocket pioneer Konstantin E. Tsiolkovski and two early publications by his American counterpart, Robert H. Goddard. The Soviet publications, carried aboard Soyuz, were returned to the Tsiolkovski Museum in Kaluga, southwest of Moscow, following

the flight while the Goddard papers aboard Apollo were delivered to the National Air and Space Museum of the Smithsonian Institution in Washington, D.C.

Two months after the end of the flight the three astronauts and the two cosmonauts, accompanied by their wives and 10 of their children, visited each other's homelands. The tour of the Soviet Union, from September 20 through October 4, encompassed seven cities: Moscow, Leningrad, Sochi, Novosibirsk, Tbilisi, Kiev, and Volgograd. The U.S. tour, from October 12 through 26, took the crews to Washington, Chicago, Omaha, Salt Lake City, San Francisco, Los Angeles, Lake Tahoe, Atlanta, Nashville, and New York. At the headquarters of the United Nations in New York, the crews jointly presented to U.N. Secretary-General Kurt Waldheim the U.N. flag that had been in Soyuz at the time of launch and was returned to Earth via Apollo.

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Возвращение

The Reentry

With all its technical complexity and sophistication, the nine-day Apollo Soyuz mission was about to pass into history as one of the most trouble-free space flights ever made until the reentry into the atmosphere by the American crew in the flight's final minutes.

For the crew and the ground controllers, life had been about as untroubled as it could be during a manned space flight. Attention had been dominated by the meetings between astronauts and cosmonauts, the conduct of scientific and technological experiments, and the numerous routine tasks involved in operating and living in a spacecraft.

Only a few minor problems had punctuated the flight and those did not pose any serious hazards or interfere with the successful completion of all major flight objectives.

So well had the project adhered to the flight plan that one spokesman in Apollo Control at Houston complained, "It's so calm down here, we feel underworked."

Dr. Glynn S. Lunney, the American Apollo Soyuz Test Project Technical Director, said: "I could not be more happy with the way the flight has gone. It has been just beautiful."

Only a day before reentry, astronaut Slayton had shown in a wry way that the crew felt no strains. During an unprecedented live press conference—at which reporters asked questions directly of the astronauts, rather than having them read by spacecraft communicators as in the past—a reporter at the NASA space

center in Houston asked Slayton whether the flight was easier or more strenuous for him than he had expected. Slayton replied: "From a physical point of view, I haven't done anything my 91-year-old aunt in Wisconsin couldn't have done equally well."

The most serious complaint up to reentry was no bigger than one voiced by Brand that he and his colleagues were so busy with their numerous tasks in the relatively small interior living area of the spacecraft that "we need a traffic cop up here to direct who's going which way and when. We are always bumping into each other."

Suddenly, when most close followers of the mission already were writing off the project as happily concluded, the situation changed to near-catastrophe.

During the parachute descent of the Apollo Command Module, Stafford, Brand, and Slayton noticed fumes that they described as a yellow gas inside the capsule. The gas caused all three astronauts to experience eye irritations and severe coughing as they descended.

They first noticed the gas when their Command Module was at an altitude of about 6900 meters (23 000 feet), a few minutes before splashdown in the Pacific Ocean 430 kilometers (270 miles) west of Hawaii at 5:19 p.m. (EDT) Washington time, Thursday, July 24.

The astronauts' plight was obscured by poor radio transmission conditions and the welter of operational communications required for the recovery. Mention of fumes and odors was at first not considered unusual by those who heard the references because similar reports had been made by other crews during reentry. Stafford himself had reported odors during reentry on his space flights in 1965, 1966, and 1969. Engineers suspected the odors came from seared sections of the heat shield or from the explosive charges that open the parachute compartment. There was no immediate reason to believe that the July 24 fumes were different, or of a more noxious nature.

Almost immediately after hitting the ocean, the funnel-shaped

Command Module turned upside down—its blunt end facing upward and the pointed end in the water. Such an inversion is not unusual and, by itself, is not hazardous. Flotation balloons attached to the module gradually righted it. But, in the interval of five minutes, the astronauts were in a precarious situation.

With the capsule floating in an upside-down position, the astronauts faced downward and were held in their couches by seat straps. Oxygen masks, in drawer-like compartments behind the couches, were very difficult to reach in that situation.

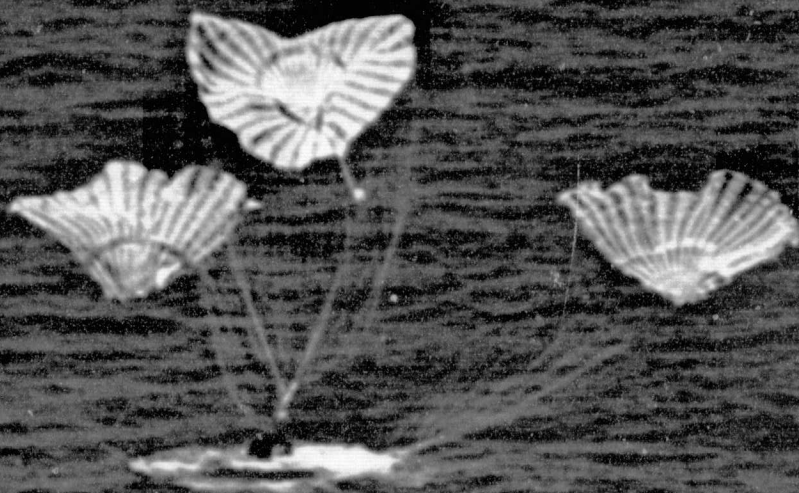
Stafford released his straps, dropped to the bottom of the gas-filled Command Module, then climbed back up over the couches to retrieve three masks. He gave one each to Slayton and Brand and put the third on himself. Then, noting that Brand had fainted, he and Slayton adjusted Brand's mask. Brand regained consciousness in about a minute.

Physicians later theorized that Brand's fainting may not have been related to the gas. Instead it may have been caused by temporary low blood pressure—called orthostatic hypotension—which many astronauts have experienced, though less seriously. It comes from the sudden change from weightlessness in space to exposure to the normal pull of the gravity of the Earth, or the force equal to several times that normal pull which is generated by deceleration during reentry.

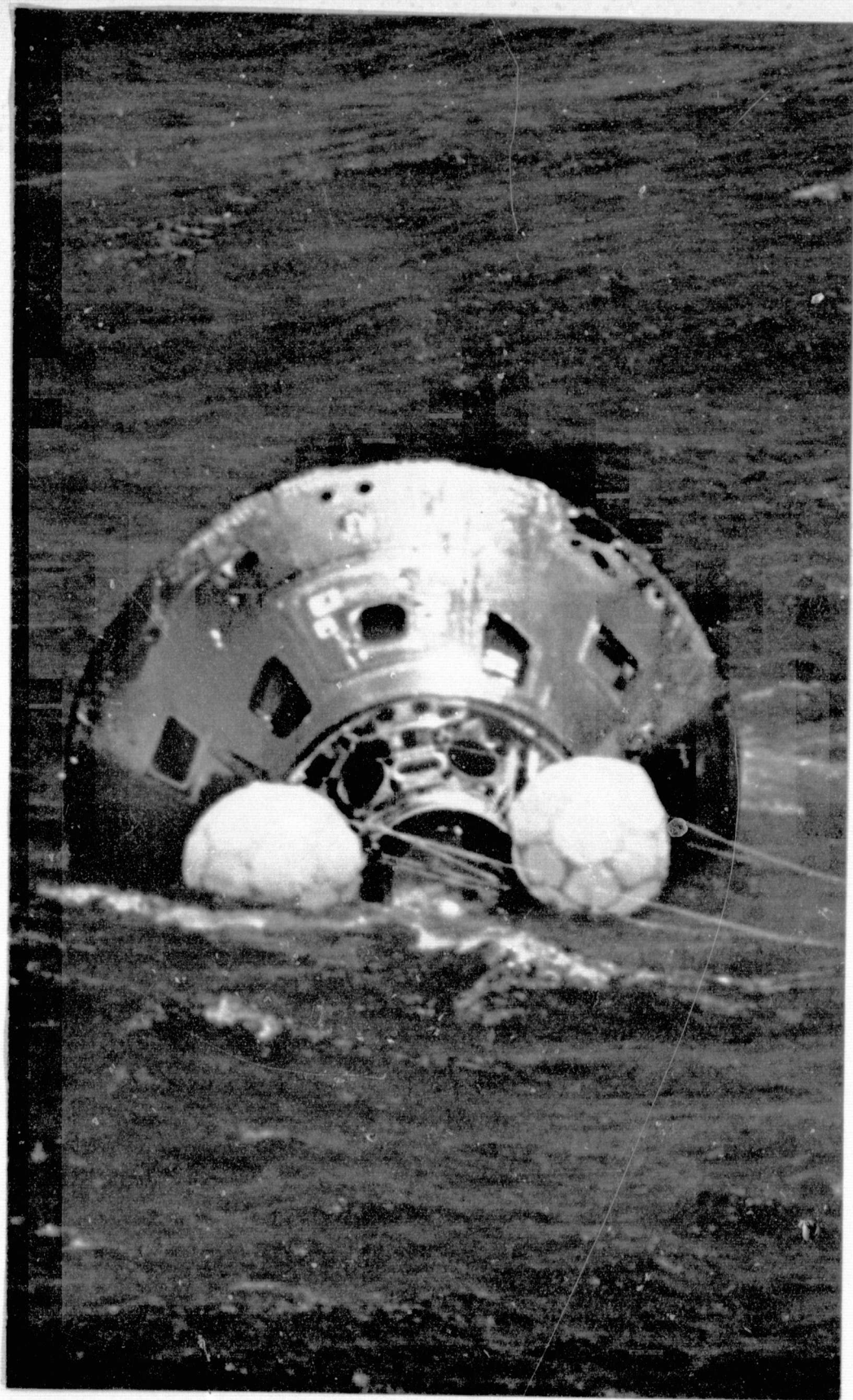
After the capsule had righted itself and there was no longer any danger of seawater pouring in, Stafford opened the hatch slightly to allow fresh air to enter.

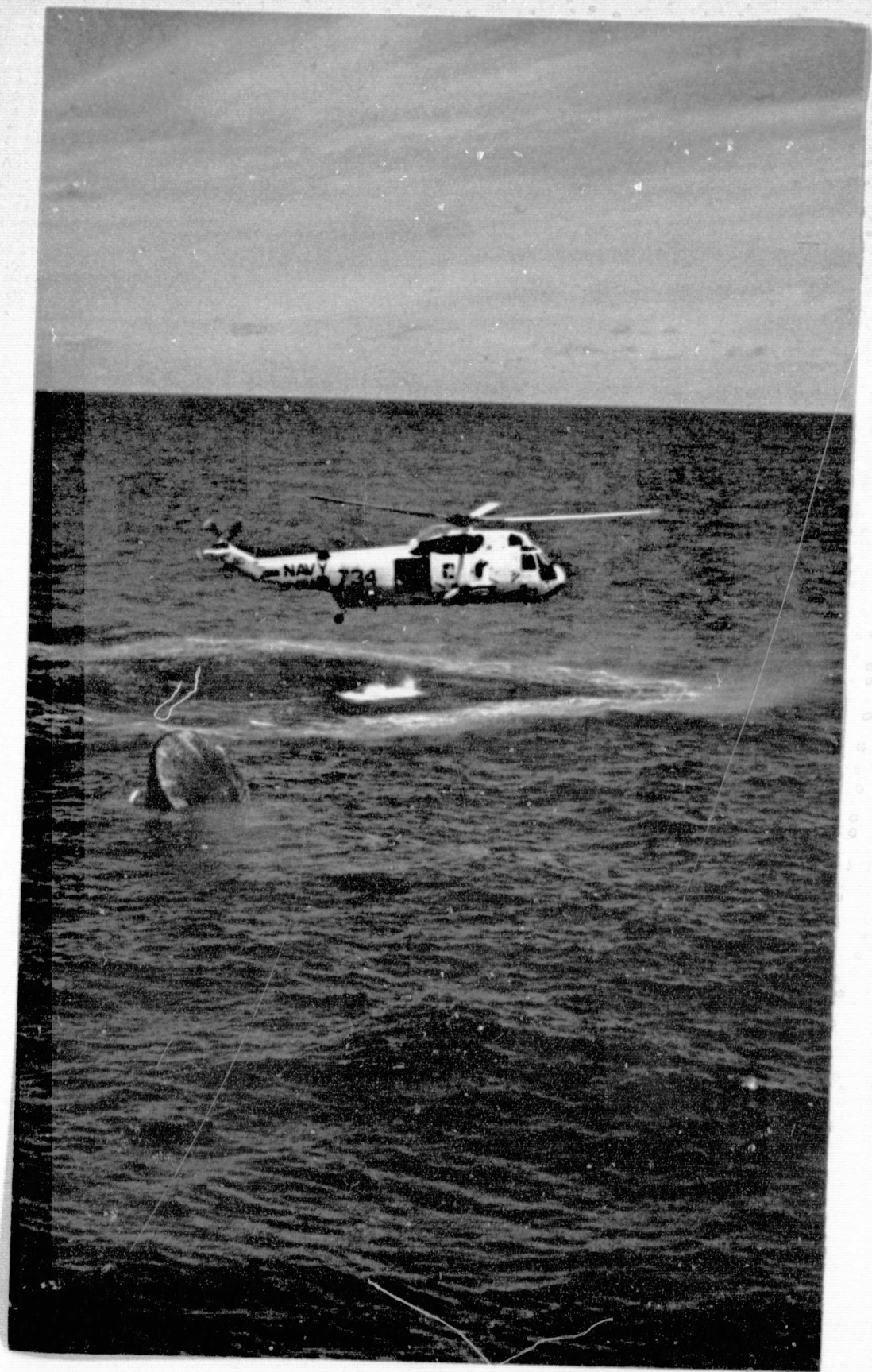
The astronauts remained inside their capsule, as planned, until it was lifted to the deck of the recovery ship, the aircraft carrier *U.S.S. New Orleans*, which had been stationed 7200 meters (8000 yards) from the splashdown point. As the men emerged from the spacecraft, they appeared to be in excellent health and spirits.

During the welcoming ceremonies on the carrier deck, television viewers and ceremony participants had no inkling of what the men had endured only minutes earlier. Instead, the audiences



ORIGINAL PAGE IS
OF POOR QUALITY





Page 100, Apollo
splashdown.

Page 101, Balloon-like
bags of Command
Module are inflated
by Apollo crew
to right overturned
spacecraft.

Opposite, helicopter
hovers above overturned
Command Module
shortly after
splashdown.

Below, Command
Module is secured
by frogmen. U.S.S.
New Orleans, the
recovery ship, is on
horizon.



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OF POOR QUALITY

*Members of recovery
team peer through
window.*



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*Left to right, Stafford,
Slayton, and Brand
receive telephoned
congratulations from
President Ford aboard
their recovery ship, the
U.S.S. New Orleans.*

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C-2

saw them apparently comfortable and pleased as each of the three spoke briefly on worldwide television and then conversed with President Ford who called them by radiotelephone from the White House.

That the men were seen to wipe their eyes repeatedly was discounted by observers as a consequence of their coming into the bright sunshine on the carrier deck from the relatively dark interior of the spacecraft. Nor did most listeners take any clue to the serious problem from Slayton's almost casual mention in his brief remarks that he and his fellow crewmen were glad to see the recovery team through the spacecraft's window after "we picked up a little smoke on the way . . ."

Only after the ceremony, when the crew entered the mobile medical laboratory on the *New Orleans* to begin the routine five-hour postflight physical examinations, did the men complain about discomfort and chest pains whenever they breathed deeply.

Physicians ordered the trio to the ship's sickbay for observation. Additional examinations showed all were suffering from irritation of the respiratory tract. They were given cortisone to relieve the irritation. Upon the arrival of the *New Orleans* in Honolulu the next day, July 25, the men were ordered to postpone their planned return flight to Houston. Instead they were admitted to Tripler Army Hospital in Honolulu for further observation.

Meanwhile, investigators promptly reviewed recordings of the crew's conversations and examined data automatically registered by spacecraft instruments in an effort to reconstruct events during the crucial minutes before splashdown.

This investigation showed that the crew's attention had apparently been diverted by interference in communications lines (there was a loud unexplained squeal in the recording of communications through the headsets), and the men had delayed turning on the two switches that activate the Apollo's automatic Earth Landing System. Like an automatic clothes washer that works through several cycles, or an automatic record player, the system

follows a prescribed sequence of operations without human intervention—but only after being turned on.

As the Command Module bored into the atmosphere, the astronauts activated its parachutes, which deployed properly. But the crew failed to immediately turn off the small rocket thrusters that keep the capsule properly positioned before the parachutes open. This thruster turnoff would have occurred automatically if the Earth Landing System had been activated.

One thruster outlet was near the intake through which fresh air was sucked into the Command Module during its descent and after splashdown. Thus the thruster propellant's oxidizer was allowed to enter the module and the gas the astronauts saw, smelled, and inhaled was what had been feared most by the physicians—nitrogen tetroxide, a very toxic chemical agent that can be fatal if inhaled in large concentrations, or can cause severely disabling lung disease. Exposure to the gas often leaves victims easy prey to pneumonia and other dangerous illnesses.

After three days in the hospital, the men were released for 10 days of rest and medical observation in Hawaii where their wives joined them. There, the astronauts developed none of the feared complications, recovered quickly, and were given a clean bill of health as far as the gas exposure was concerned.

Concern was revived by the announcement on August 19 that Slayton would undergo surgery to explore a spot on his lung. The lesion was found to be benign after surgery August 26. Doctors reported it was not the result of inhaling the gas, but had begun its development before the flight. Ironically, the lesion might have remained undiscovered if not for the accidental inhalation of nitrogen tetroxide and the subsequent X-ray examinations.

The end of the Apollo Soyuz flight simultaneously closed the books on a historic chapter in America's space program. The Apollo splashdown completed the last flight for that spacecraft—the vehicle that, in its seven years of use, carried 38 Americans through space in 15 separate flights. These included nine missions

around the Moon of which six led to landings by a total of 12 men on the lunar surface. It also was the Apollo spacecraft that served as a "space taxicab" between Earth and the experimental Skylab space station in 1973 and 1974.

The Apollo was the last of America's disposable manned spacecraft (those usable for only one flight). Its successor will be able to return to space for numerous missions.

Перспективы

The Look Ahead

For the remainder of the 1970's there are no contenders to replace the Apollo Soyuz Test Project as the decade's most ambitious international space mission. Such flights require years of lead time for the training of crews and the preparation of equipment.

But the trend is in the direction of more international cooperation in space. Looking beyond the 1970's, the prospect is for international space projects on an expanded scale. Complex new systems will be available for international use and personnel from different nations will routinely live and work in the same orbiting spacecraft. The foundations for these missions are already in place.

Even as the last Apollo was rising from its launchpad at the Kennedy Space Center, workmen a few kilometers away were busy preparing for the next major advance in space operations.

They were building the huge runway that is to become the landing site for the next generation of U.S. manned spacecraft: the reusable Space Shuttle. International cooperation is part and parcel of the Space Shuttle's planned space operations beginning in the 1980's.

While U.S. engineers are constructing and testing the first Space Shuttle, a Spacelab for use aboard the Space Shuttle is being built by the European Space Agency in a cooperative project involving nine member countries: Belgium, Denmark, France, West Germany, Italy, The Netherlands, Spain, Switzerland, and

the United Kingdom, and Austria, a nonmember country. The Spacelab can be outfitted with a variety of scientific and technological experiments, with tools for manufacturing products in weightlessness, or with instruments for observing astronomical objects or the Earth.

In some of these experiments and applications it will be desirable or necessary that the scientists and engineers themselves, or their trained technicians, accompany the equipment into space to adjust it or to supplement observations with judgments that cannot be made by machines.

A regular crew of two U.S. astronauts and a mission specialist in the Space Shuttle cockpit may have up to four international scientists on missions as long as 30 days.

As space becomes more readily accessible through use of the Space Shuttle, nations may wish to send geologists, hydrologists, cartographers, and other Earth resource specialists into orbit to help improve agricultural output; plan civil engineering projects such as roads, bridges, and dams; aid discovery and management of mineral deposits; and in other ways speed economic development.

Such international cooperation in manned space flight is a logical extension of expanding space capabilities based in large measure on international cooperation in unmanned space projects in the 1960's. In that decade, many nations shared information gathered by weather satellites and cooperated in the use of communications satellites.

The U.S. experimental Applications Technology Satellite 6, which provided key communication services for Apollo Soyuz (see Chapter 3), followed that activity with an assignment of far greater significance for future cooperation between nations. It was moved from above the Atlantic Ocean to a point directly above Lake Victoria in East Africa where it could receive signals from India and relay them to television receivers across the Indian subcontinent.

The Government of India used the American satellite in a

one-year experiment to bring instructional television programs on agricultural productivity, health, and family planning to 5000 villages not able to receive television from existing transmitters on the ground.

The most widely known example of international cooperation with communications satellites is, of course, the 12-year-old global system of the Intelsat organization now owned by nearly 100 nations, which are linked with each other via satellites for telephone and television services.

In the not too distant future, it should become feasible to develop space stations staffed by perhaps dozens of specialists who will manufacture products under weightless conditions, make astronomical and Earth observations, and conduct other research. Before such space installations become a reality, the world is likely to see multinational passenger lists on many Space Shuttle flights. Citizens of different nations working together in orbit—men and women—are bound to become commonplace. The televised Apollo Soyuz scenes of persons from different nations together in the same spacecraft were indeed glimpses into the future.

Table A
Brezhnev-Ford
Statements to Crews

The following statement was read to the American and Soviet Apollo Soyuz Test Project crews by an announcer in Moscow on behalf of Communist Party Secretary Leonid I. Brezhnev at 2:23 p.m., July 17, 1975, Washington time (EDT) (9:23 p.m. Moscow time) about two hours after the Apollo and Soyuz spacecraft had completed the first international docking of spacecraft:

This is a reading to Aleksey Leonov, Valeriy Kubasov, Thomas Stafford, Vance Brand, and Don Slayton. In the name of the Soviet people and from myself personally, I congratulate you on a significant event: the first docking of a Soviet spacecraft, Soyuz 19, and an American spacecraft, Apollo.

The whole world is observing with great attention and delight your responsible work that you are performing in carrying out the scientific experiments. The successful docking proved the correctness of the decisions which were made in joint cooperation and friendship between Soviet and American designers, scientists, and cosmonauts.

It could be said that the Soyuz Apollo is a prototype of future orbital space stations.

Since the time of the launch of the first Sputnik and the first flight of man into space, space has become an arena of international cooperation. Detente, positive movement ahead in Soviet-American relations, has created the proper conditions for the first international space flight.

New possibilities are opening up for fruitful development of scientific cooperation between countries and the peoples in the interest of peace and progress for all humanity.

The following statement was made by President Ford via radio-telephone conversation from the White House to the U.S. and Soviet crews of the Apollo Soyuz Test Project at 2:36 p.m., July 17, 1975, a few minutes after two American astronauts entered the Soyuz, when, for the first time in history, men from two nations were inside the same orbiting spacecraft:

Gentlemen, let me call to express my very great admiration for your hard work, your total dedication in preparing for this joint flight.

All of us here in Washington, in the United States, send to you our warmest congratulations for your successful rendezvous and for your docking, and we wish you the very best for a successful completion of the remainder of your mission.

Your flight is a momentous event and a very great achievement not only for the five of you, but also for the thousands of American and Soviet scientists and technicians who have worked together for three years to insure the success of this very historic and very successful experiment in international cooperation.

It has taken us many years to open this door to useful cooperation in space between our two countries. I am confident that the day is not far off when missions made possible by this first joint effort will be more or less commonplace.

We all look forward to your safe return . . . and we look forward to talking with you on Earth again when you do end your flight.

President Ford then asked each of the five crew members a question and conversed with them for several minutes.

Таблица Б

Table B
Times of Major Events

	Eastern Daylight Time	Date	Moscow Time	Date
		July		July
Launch of Soyuz (at Cosmodrome, Baykonur, Kazakhstan, U.S.S.R.) ----	08:20	15	15:20	15
Launch of Apollo (at Kennedy Space Center, Florida, U.S.) -----	15:50	15	22:50	15
First docking (Apollo Soyuz connect to each other) -----	12:09	17	19:09	17
Hatches opened between Apollo's Docking Module and Soyuz -----	15:17	17	22:17	17
First handshake (Stafford-Leonov) through hatch -----	15:19	17	22:19	17
Stafford enters Soyuz, becomes first person inside orbiting spacecraft of another nation -----	15:20	17	22:20	17
Slayton enters Soyuz, becomes second person to enter orbiting spacecraft of another nation -----	15:30	17	22:30	17
Astronauts (having ended first visit and left Soyuz) close hatch ----	18:51	17	01:51	18
Second crew transfer begins (Brand goes to Soyuz; Leonov goes to Apollo) -----	05:45	18	12:45	18

	Eastern Daylight Time	Date	Moscow Time	Date
		July		July
Third crew transfer begins (Stafford and Leonov go to Soyuz; Brand and Kubasov go to Apollo) ---	12:03	18	19:03	18
Fourth crew transfer begins (Kubasov returns to Soyuz, and Stafford returns to Apollo; thus all crew members are back in their own craft) -----	16:45	18	23:45	18
Farewell handshake (last face-to-face meeting of crews before hatch separating the two craft is resealed for the last time) -----	16:49	18	23:49	18
First undocking -----	08:03	19	15:03	19
Second docking (for additional test and experience of the new docking system) -----	08:34	19	15:34	19
Final undocking (last physical contact between Apollo and Soyuz) ---	11:26	19	18:26	19
Soyuz landing (in Kazakhstan Republic, U.S.S.R.) -----	06:50	21	13:50	21
Apollo splashdown (in Pacific, 432 kilometers (270 miles) west of Hawaii) -----	17:19	24	00:19	25

Soyuz flight time (from launch to landing):
142 hours, 30 minutes (5 days, 22 hours, 30 minutes)
Apollo flight time (from launch to splashdown):
217 hours, 29 minutes (9 days, 1 hour, 29 minutes)

TOTAL REVOLUTIONS

Soyuz -----	97
Apollo -----	138

Time spent by Soyuz crew inside Apollo
(during 2 days of joint activities):

	Hours:Minutes
Leonov -----	5:43
Kubasov -----	4:59
Total for Soyuz crew -----	10:42

Time spent by Apollo crew inside Soyuz
(during 2 days of joint activities):

	Hours:Minutes
Stafford -----	7:10
Brand -----	6:30
Slayton -----	1:35
Total for Apollo crew -----	15:15

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Таблица В

Table C
"Firsts" Achieved by
Apollo Soyuz

- First space flight involving crews and spacecraft of more than one nation
- First linking in orbit of spacecraft of more than one nation
- First detection of a pulsar outside our own galaxy
- First detection of stars emitting extreme-ultraviolet radiation; four detected; one found to be hottest "white dwarf" type known
- First separation of live biologic materials in space by electrophoresis, an accomplishment with implications for medical and biological research
- First communications between a manned orbiting spacecraft and ground controllers via an orbiting unmanned communications satellite

Таблица Г

Table D
Major Officials

United States of America:

Dr. James C. Fletcher
Administrator
National Aeronautics and
Space Administration

Dr. George M. Low
Deputy Administrator
National Aeronautics and
Space Administration

John F. Yardley
Associate Administrator
for Manned Space Flight
National Aeronautics and
Space Administration

Chester M. Lee
Apollo Soyuz Test Project
Program Director
National Aeronautics and
Space Administration

Dr. Christopher C. Kraft, Jr.
Director, Johnson Space Center
National Aeronautics and
Space Administration

Dr. Glynn S. Lunney
Apollo Soyuz Test Project
Technical Director
Johnson Space Center
National Aeronautics and
Space Administration

Arnold W. Frutkin
Assistant Administrator
for International Affairs
National Aeronautics and
Space Administration

Union of Soviet Socialist Republics:

Vladimir Kotelnikov
President
Academy of Sciences of the U.S.S.R.
Academician Mstislav V. Keldysh
former President
Academy of Sciences of the U.S.S.R.

Academician Boris N. Petrov
Chairman, Council for
International Cooperation in the
Exploration and Use of Outer Space
Academy of Sciences of the U.S.S.R.

Academician Vladlen S. Vereshchetin
Vice chairman, Council for
International Cooperation in the
Exploration and Use of Outer Space
Academy of Sciences of the U.S.S.R.

Professor Konstantin D. Bushuyev
Apollo Soyuz Test Project
Technical Director

General Vladimir A. Shatalov
Chief of Astronaut Training in the U.S.S.R.

Table E
Scientific Experiments

This table lists the name (and in parentheses the official NASA numerical designation) of the 28 scientific experiments involving the Apollo spacecraft and crew. The five experiments carried out jointly by the Apollo and Soyuz crews are identified with an asterisk (*). Experiments preceded by a plus sign (+) were discussed in Chapter 6.

Space Science**Astronomy**

1. *+Soft X-Ray (MA-048)*.
This instrument was used to observe and record certain X-ray radiations from stars and galaxies.
2. *+Extreme-Ultraviolet Survey (MA-083)*.
Scientists called this instrument "a small telescope with the world's largest mounting." The instrument was rigidly mounted on the Apollo Service Module. The astronauts had to turn the entire Apollo spacecraft to point the instrument at the desired celestial target.
3. *Helium Glow Detector (MA-088)*.
This instrument measured the temperature, movement, and abundance of helium that is part of the interplanetary medium and the Earth's upper atmosphere.
4. ***Artificial Solar Eclipse (MA-148)*.
In this experiment, the Apollo spacecraft served to eclipse the Sun as photographs of outer solar regions were taken by the Soyuz crew. For comparative purposes, ground astrono-

mers observed the Sun simultaneously. The photos also are being used to study accumulations and distribution near the orbiting Apollo of emissions from the spacecraft's thrusters and other exhaust gases in weightlessness.

5. *Crystal Activation* (MA-151).

The purpose of this experiment was to develop techniques and calibrate instruments for detecting certain kinds of space radiations on future flights by unmanned spacecraft. Crystals (of pure germanium and sodium iodide) were stored in a container aboard the Apollo. These crystals are known to be sensitive to gamma radiation. After the Apollo's return to Earth, the crystals were examined for traces of gamma radiation. In this way scientists expect to determine the usefulness of these crystals as radiation detectors.

Earth Environment

6. **Ultraviolet Absorption* (MA-059).

Invisible ultraviolet light was beamed from the Apollo to a reflector mounted on the nearby Soyuz which bounced the light back to a detector on the Apollo.

7. *Stratospheric Aerosol Measurement* (MA-007).

This experiment tested space techniques and instruments designed to determine the amount of aerosols—tiny particles—floating in the Earth's atmosphere for long periods. Aerosols have a variety of origins such as volcanic eruptions, weather systems, industrial smoke, large forest fires, and meteoroids disintegrating as they fall toward the Earth.

8. **Earth Observations and Photography* (MA-136).

With their own eyes and with instruments, the astronauts observed the continents and oceans as they can be seen only from orbital altitudes. The Apollo Soyuz experiments were designed to aid Earth resource analysis and management.

9. *Doppler Tracking* (MA-089).

By measuring and comparing slight irregularities in the flightpath of two bodies orbiting the Earth, scientists expect

to learn about differences in the Earth's gravitational attraction. These differences at separate locations are brought about by uneven distribution of metallic components inside the Earth. The measurements were made by electronic tracking of the Apollo and the Docking Module after they separated shortly before reentry.

10. *Geodynamics* (MA-128).

The purpose of this experiment was the same as the experiment on doppler tracking (MA-089). MA-128 attempted to achieve the same result through electronic tracking of two satellites. One satellite was Apollo and the other tracked satellite was the U.S. Applications Technology Satellite (ATS) 6. The ATS 6 was above Kenya, East Africa, in a stationary orbit (where it completed one revolution every 24 hours and, thus, appeared to stand still as seen from the Earth's surface). Comparisons of the Apollo and satellite orbits are expected to help scientists detect gravity anomalies caused by mass concentrations ("mascons") of metallic materials deep inside the Earth.

Life Science

11. *Light Flash* (MA-106).

This experiment sought to measure the character and frequency of high-energy cosmic radiation passing through human central nervous system cells in Earth orbit. Exposure to such radiation could become of major concern if manned missions of two to three years' duration are planned. On Earth, living organisms are protected from much of this radiation by the atmosphere, which serves as a filter. The astronauts, after donning special light-tight masks (helmets) and letting their eyes adapt to the darkness, recorded data on all light flashes caused by cosmic radiation passing through the retinas of their eyes. Their individual reports of shape, position, and apparent motion for each flash were compared with radiation detection instruments on Apollo.

12. *Biostack* (MA-107).

This experiment to determine the effect of cosmic radiation on dormant biological cells used such subjects as plant seeds and brine shrimp eggs stacked in eight layers in a sealed container. Between each layer were cosmic radiation detectors. After the flight, the specimens were allowed to grow and develop while being watched for any abnormalities or mutations traceable to radiations received while above the protective Earth atmosphere.

13. **Zone Forming Fungi* (MA-147).

This experiment was aimed at determining the influence of space radiations on living cells.

14. **Microbial Exchange* (AR-002).

This experiment and the two immediately following were designed to learn more about the spread of bacteria and the human immune system—the body's natural defense against invading disease-causing germs. Previous space flights have shown that in an orbiting spacecraft, where few microbes can escape or new ones enter, the varieties of microbes tend to diminish, but the surviving varieties increase in numbers and become dominant. This experiment was carried out by examinations of skin swabs of the astronauts and cosmonauts and swabs of the inside of their spacecraft before and after their meeting in orbit. The experiment also was expected to provide information on the migration of microbes between the crews and the two spacecraft.

15. *Cellular Immune Response* (MA-031).

Blood samples (lymphocytes) taken from each astronaut before the flight were compared with the samples taken after the flight. The before-and-after comparison is expected to show response by the men's immune system that may be due to alterations in the spacecraft's microbe population. (See preceding microbial exchange experiment.)

16. *Polymorphonuclear Leukocyte Response* (MA-032).

The purpose of this experiment is identical with that of the

preceding cellular immune response experiment. Blood samples taken before and after the flight were compared in different tests.

17. *Killifish Hatching and Orientation* (MA-161).

An extension of experiments performed in the Skylab program, this experiment used motion picture film, astronaut observation, and postflight analysis to examine the weightless development of small fish embryos and the orientation behavior of hatchlings. Fry hatched in Skylab had exhibited none of the disorientation shown in space by ground-hatched fingerlings. A sealed plastic bag on Apollo contained five compartments. In each compartment was water and at least 10 preconditioned *Fundulus* fry for the orientation studies. In the second part of the experiment, *Fundulus heteroclitus* embryos representing key development stages were carried throughout the mission for postflight comparison of vestibular functioning and microscopic and physiological changes with embryos that did not fly.

18. **Electrophoresis Technology Experiment System* (MA-011).

This technology experiment was designed to demonstrate means of transporting samples of living cells into space, separating them by electrophoresis, and returning the separated cells still living to Earth for further investigation of their properties. The separation runs were performed in cylindrical columns of static fluids and the cell samples were preserved before and after separation in frozen form.

19. **Electrophoresis* (MA-014).

This was an attempt to develop a flowing-fluid technique that would permit continuous electrophoretic separation of selected living cells. The technique hopefully would lend itself eventually to the manufacture in space of vaccines and other products for medical uses of a purity not obtainable on Earth.

Applications

20. **Multipurpose Electric Furnace Experiment (MA-010).*
A 29.2-centimeter (11.5-inch) long, 5.2-kilogram (11.5-pound) electric-powered furnace (and associated cooling equipment) mounted on the wall of the Apollo's Docking Module was used by the astronauts to melt and solidify a variety of materials. One of the advantages of doing this in prolonged weightlessness (which cannot be duplicated on Earth) is that the heavier components of a mixture do not sink to the bottom. Mixtures can be cooled and solidified uniformly. Earth mixtures also are disturbed during cooling when hotter portions rise and cooler portions sink. These stirring motions—called convection currents—are absent in weightlessness, allowing mixtures to solidify evenly. Experts envision that this experiment will lead to commercial production in space of materials impossible to create on Earth.
21. *Surface-Tension-Induced Convection (MA-041).*
Although weightlessness allows mixtures of metals to solidify evenly, undisturbed by the settling of heavier components or uneven heating and subsequent convection currents, there remains the possibility of adverse effects from convection caused by "surface tension." In this experiment, the astronaut melted lead containing small amounts of gold and allowed the molten materials to mix and cool. The solidified mixtures were returned to Earth for scientists to cut into thin slices to determine the distribution of the gold. In this way the researchers will learn if convection occurred through surface tension and what its effect was on the mixture.
22. *Monotectic and Syntectic Alloys (MA-044).*
The astronauts melted and resolidified pairs of metals for comparison with identical mixtures processed in the same way on Earth. The purpose of the experiment was to find out if new kinds of materials can be made in space with physical and electrical properties unobtainable on Earth.

23. *Interface Marking in Crystals (MA-060).*

Germanium crystals were partly melted and then regrown under slightly different conditions such as different cooling temperatures. Electric pulses produced momentary growth changes that helped pinpoint rates of growth during post-flight analysis. The purpose of the experiment was to help determine the best techniques for growing crystals with predictable electronic constants and whether they can eventually be grown commercially in space.

24. *Processing of Magnets (MA-070).*

Bismuth-manganese samples were melted and then cooled so as to resolidify at controlled rates. The purpose of this experiment was to determine whether such magnetic materials can be processed in weightlessness to take on improved permanent magnetic qualities. Strong permanent magnets can be used to substitute for electromagnets in motors in the future; as "levitators" to suspend high-speed trains that float magnetically above the rails; and as magnetic bearings in flywheels used to store energy or in durable, superaccurate gyroscopes for navigation on space flights to other planets.

25. **Crystal Growth From the Vapor Phase (MA-085).*

A continuation of work initiated with the Skylab space station, this experiment used semiconducting compounds of germanium sealed in tubes with tiny amounts of iodine. Each sample compound was held at one end of its tube, and when the tube was heated in flight, the end with the sample was the hottest. The test materials were converted to vapor by both ordinary evaporation and chemical reaction with the iodine. The vapor then condensed in the form of crystal plates on the cooler parts of each tube. Postflight analysis confirmed that the crystals were far more perfect than the best produced on the ground and that the rates of crystal growth, much higher than expected, were high enough to be considered practical for production processes.

26. *Halide Eutectics (MA-131).*

Mixtures of sodium chloride and lithium fluoride were melted by the astronauts and then resolidified. As expected, the resulting solid material consisted of very regular, continuous arrays of fibers (of lithium fluoride) embedded in sodium chloride. This material can be used to transmit infrared light, and thus may lend itself to picture transmissions. The fibers also can be extracted and used in fiber-optics applications. The light-transmitting capacity of the fibers was significantly better than that of similar materials made on the ground.

27. **U.S.S.R. Multiple Material Melting (MA-150).*

Mixtures of materials melted and resolidified on Earth invariably have numerous imperfections, such as uneven distribution of component materials and hollow spaces. To study effects of solidification in weightlessness, three small cylinders containing test materials were processed in the Apollo's electric furnace. One cartridge contained a pressed aluminum pellet with small tungsten spheres embedded inside it. The second contained a germanium rod with 0.5 percent silicon. The third contained powdered aluminum.

28. *Crystal Growth (MA-028).*

In this experiment, scientists wanted to learn if better control of crystal growth from water solutions could be achieved in weightlessness where convection currents were suppressed. Each of six crystal growth units had three compartments. The center compartment held pure water, and the two outer compartments contained different salt solutions. The astronauts opened valves between the compartments so that the salt solutions flowed to the center compartment where their salts mixed and formed small crystals. The astronauts observed and photographed the process at intervals and brought the units back to Earth for examination.

Таблица Е

Table F
Major Apollo Contractors

Rockwell International	Apollo Command and Service Module, Docking Module, Docking System, spacecraft support
Space Division	
Downey, California	
Rockwell International	Saturn rocket engines and support
Rocketdyne Division	
Canoga Park, California	
General Electric Company	Automatic checkout equipment support and launch vehicle ground support equipment
Valley Forge Space Center	
Philadelphia, Pennsylvania	
Chrysler Corporation	S-IB (Saturn rocket's first stage) and launch support
Space Division	
New Orleans, Louisiana	
McDonnell Douglas Corporation	S-IVB (Saturn rocket's upper stage) and launch support
Huntington Beach, California	
IBM Federal Systems Division	Instrument unit (the automatic control system, or "brain," of the rocket) and its launch support
Gaithersburg, Maryland	
ILC Industries	Space suits
Dover, Delaware	
The Boeing Company	Reliability and quality assurance at the Johnson Space Center, Houston, Texas, and at Launch Complex 39 at the Kennedy Space Center, Florida; also, contractor for ground support equipment operations
Seattle, Washington	
Xerox Corporation	Digital evaluator
Rockville, Maryland	
Bendix Corporation	ST-124 Platform (component in guidance system that helps stabilize the rocket during flight)
Peterboro, New Jersey	